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Neuro-Fuzzy SVD Technique for Image Recognition and Safety in Construction Site

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Abstract: This paper presents a novel computer vision technique of intelligent recognition of safety in construction sites. The proposed technique relies on a new methodology for Neuro-Fuzzy Singular Value Decomposition (NFSVD). This methodology utilized unmanned safety worker's wears. Where within a construction site entranced a multi-camera is used and fixed on a special frame inside the security Cabin. Before the workers allowed for entering the construction site, an automatic detecting, and an intelligent matching system has the ability to recognize the worker's dress shapes and colors through a multi snap image. To improve the success of this methodology, the proposed technique empirically investigated, analyzed and verified to check the image frame quality, accept and reject indication, real-time complexity, diffusion, confusion and PSNR. The results performed by this technique demonstrated the robustness and reliability of this methodology for safety in the construction field.

Keywords: 3D Image processing, Image Recognition, Singular value decomposition, workers Safety, Neuro-Fuzzy system.

1 Introduction

Safety is one of the most important pillars for any construction project. It's cost tens of thousands of dollars for small projects, not to mention major projects. Construction workers are exposed to a variety of health hazards every day. These men and women have the potential for becoming sick, ill and disabled for life. These hazards include, but are not limited to: chemical, physical, biological hazards. Special consideration will be given to occupational noise exposure in construction. Employers have the responsibility to protect the safety and health of the worker. This paper will help prepare an employer or its designated representative (job-site competent person) to understand and protect the occupational health hazards in construction. The employer can use the technology by using camera system to be sure, so that the employees will be saved and protected. However, this can be achieved by using the proposed Neuro-Fuzzy Technique and SVD for Image Recognition and Safety in the construction site. As SVD is used to decompose any square or non-square digital image matrix into three orthogonal matrices that contain the useful features of the image so, it can help to select the dominant features in a digital image.

1.1 Motivation

Most of the researches in the field of construction safety focusing on high-risk to address the injury problems. This paper covers important construction topics with new methodologies to recognize and prevent worker injury; safety in construction, online 3D image processing and recognition in construction, color recognition and worker safety in construction.

1.2 Related Works

There were many papers published in this field, the following are the literature survey of some of them;

Rosangela, et al. [1], proposed a recurrent neuro-fuzzy network structure and learning procedure. The learning procedure developed is based on two main paradigms; gradient search and associative reinforcement learning respectively. The output layer weights are adjusted via an

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error gradient method. The recurrent neuro-fuzzy network is used to develop a model of a nonlinear process. **ChiYung Lee and ChengJian Lin** [2], proposed a recurrent compensatory neuro-fuzzy system (RCNFS) is proposed for prediction of time sequence. The compensatory based fuzzy reasoning method is using adaptive fuzzy operations of neuro-fuzzy systems that can make the fuzzy logic systems more adaptive and effective. The recurrent network is embedded in the RCNFS by adding feedback connections in the second layer, where the feedback units act as memory elements. Also, an on-line learning algorithm is proposed to automatically construct the RCNFS. They are created and adapted as on-line learning proceeds via simultaneous structure and parameter learning. **Rahib, et al**. [3], described the structure and algorithms of neuro-fuzzy system for predicting future values of electricity consumption. To determine the unknown coefficients of the system, the supervised learning algorithm is used. As a result of learning, the rules of neuro-fuzzy system are formed. The developed system is applied for predicting future values of electricity consumption of Northern Cyprus. **Floriberto et al**. [4], proposed two types of recurrent techniques for fuzzy CMAC to overcome the above problems. The new CMAC neural networks are named recurrent fuzzy CMAC (RFCMAC) which add feedback connections in the inner layers (local feedback) or the output layer (global feedback). The corresponding learning algorithms have time-varying learning rates, the stabilities of the neural identifications are proven. ***Distante, et al.*** [5], they presented a wide dataset for indoor surveillance applications acquired by a state of the art range camera. The main issue is the definition of a common basis for the comparative evaluation of the performance of vision algorithms. However, the training time consuming and tuning determination of multi layers backpropagation neural networks makes them more powerful for fuzzy systems. The combination of fuzzy system and neural network allows the increase computational efficiency of the software products. Neuro-Fuzzy system combines the learning capabilities of neural networks with the linguistic rule interpretation of fuzzy inference systems.

In the field of colour detection problems. **Manpreet Kaur** [6], presented a method that deals with object detection using red colour parameter both for still image and real time Images. The results of this processing can be used in numerous security applications such as intrusion detection and in Spy robots. **Raquib et al**., [7], described the implementation of various MATLAB functions present in image processing toolbox of MATLAB and using the same to create a basic image processor having different features like, viewing the red, green and blue components of a colour image separately, colour detection and various other features (noise addition and removal, edge detection, cropping, resizing, rotation, histogram adjust, brightness control, etc.) that is used in a basic image editor along with object detection and tracking. **Theo Gevers et al**., [8], described problem of the recognition of multicolored objects invariant to a substantial change in viewpoint, object geometry and illumination. To evaluate the recognition accuracy differentiated for the various colour models, experiments have been carried out on a database consisting of 500 images taken from 3-D multicolored man-made objects. **R. Hussin**, **et al**., [9], This paper discusses the method or techniques on how to detect the mango from a mango tree. The techniques using are such as colour processing which are used as primary filtering to eliminate the unrelated colour or object in the image. Besides that, shape detection is being used where it will use the edge detection, Circular Hough Transform (CHT). This technique will determine the candidates of mango and find the circular pattern with the given radius within an image by collecting the maximum voting. The program should automatically detect the desire object and count the total number of it. **Jos´e-Juan Hernandez, et al**., [10], described object segmentation from an image is achieved using colour segmentation. This segmentation can be achieved by processing the R, G and B chromatic components. However, this method has the disadvantage of been very sensitive to the changes on lighting. Converting the RGB image to the CIE-Lab colour space avoids the lack of sensitivity by increasing the accuracy of the color segmentation. **Baris Gecer, et al**. [11], propose color-blob-based COSFIRE (Combination of Shifted Filter Responses) filters to be selective for combinations of diffuse circular regions (blobs) in specific mutual spatial arrangements. Such a filter combines the responses of a certain selection of Difference-of-Gaussians filters, essentially blob detectors, of different scales, in certain channels of a color space, and at certain relative positions to each other.

During the research process we encountered the problem of distinguishing the skin color with the other colors, for that reason we found the following published papers in this field. **Son Lam Phung, et al.** [12], This paper presented a new human skin color model in YCbCr color space and its application to human face detection. Skin colors are modeled by a set of three Gaussian clusters, each of which is characterized by a centroid and a covariance matrix. Efficient post-processing techniques namely noise removal, shape criteria, elliptic curve fitting and face/nonface classification are proposed in order to further refine skin segmentation results for the purpose of face detection. **P. Kakumanu, et al**. [13], presented skin detection technique using colour information can be a challenging task as the skin appearance in images is affected by various factors such as illumination, background, camera characteristics, and ethnicity. Numerous techniques are presented in literature for skin detection using colour. In this paper, we provide a critical up-to-date review of the various skin modelling and classification strategies based on colour information in the visual spectrum. The review is divided into three different categories: first, we present the various colour spaces used for skin modelling and detection. Second, we present different skin modelling and classification approaches. However, many of these works are limited in performance due to real-world conditions such as illumination and viewing conditions. To cope up with the rapidly changing illumination conditions, illumination adaptation techniques are applied along with skin-color detection. Third, we present various approaches that use skin-color constancy and dynamic adaptation techniques to improve the skin detection performance in dynamically changing illumination and environmental conditions. **Khamar Basha Shaika, et al**. [14], presented a comparative study of human skin color detection HSV and YCbCr color space. Skin color detection is the process of separation between skin and non-skin pixels. It is difficult to develop uniform method for the segmentation or detection of human skin detection because the color tone of human skin is drastically varied for people from one region to another.

1.3 The Contribution of This Work

This work attempts to solve the problem of safety in construction sites by using computer vision technique and Neuro-Fuzzy Singular Value Decomposition NFSVD.

The remainder of this paper is organized as follows. Section II describes the Singular Value Decomposition technique, and Section III presents SVD approach for image compression. Section IV demonstrates the neuro-fuzzy singular value decomposition. Section V exhaustive simulation and experiments the in-depth analysis, and the conclusion is given in Section VI.

2 Theory of Singular Value Decomposition

The Singular Value Decomposition (SVD) is one of the useful tools of linear algebra, it is a factorization and approximation technique which effectively reduces any matrix into a smaller and invertible and square matrix.

If we consider a matrix *A* with *m* rows and *n* columns, with m ≥ n. Then, there exist orthogonal matrices U (m × m) and orthogonal matrices V ($n \times n$) and a diagonal matrix S =diag(σ_1, σ_2, …, σ_n) ($m \times n$) with $\sigma_1 \geq \sigma_2 \geq \ldots \geq \sigma_n \geq 0$ and $\sigma_{r+1} = \sigma_{r+2} = \cdots = \sigma_n = 0$, If $\sigma_r > 0$ is the smallest singular value greater than zero then the matrix A has rank r. *A* matrix can be factorized into three matrices;

$$\boldsymbol{A = USV^T} \quad (1)$$

The column vectors of U=$[\boldsymbol{u_1}, \boldsymbol{u_2}, \ldots \boldsymbol{u_r}, \boldsymbol{u_{r+1}}, \ldots, \boldsymbol{u_m}]$ are called the left singular vectors and
V=$[\boldsymbol{v_1}, \boldsymbol{v_2}, \ldots \boldsymbol{v_r}, \boldsymbol{v_{r+1}}, \ldots, \boldsymbol{v_n}]$ are the right singular vectors.
The values σ_i are called the singular values of A.
Where, column vectors $\boldsymbol{u_i}$, for i = 1, 2, …, m, form an orthonormal set:

$$\boldsymbol{u_i^T\, u_j = \delta_{ij}} = \begin{cases} \mathbf{1} & \boldsymbol{i =\ j} \\ \mathbf{0} & \boldsymbol{i \neq\ j} \end{cases} \quad (2)$$

And column vectors $\boldsymbol{v_i}$ for i = 1, 2, …, n, form an orthonormal set:

$$\boldsymbol{v_i^T\, v_j = \delta_{ij}} = \begin{cases} 1 & \mathrm{i =\ j} \\ 0 & \mathrm{i \neq\ j} \end{cases} \quad (3)$$

Here, *S* is an $m \times n$ diagonal matrix with singular values on the diagonal.

$$S = \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & \sigma_2 & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_r & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & \sigma_{r+1} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & \cdots & \sigma_n \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 \end{bmatrix} \quad (4)$$

3 SVD Approach for Image Compression

Image compression deals with the problem of reducing the amount of data required to represent a digital image. Compression is achieved by the removal of three basic data redundancies:

1) Coding redundancy, which is present when less than optimal;
2) Interpixel redundancy, which results from correlations between the pixels;
3) Psych visual redundancies, which is due to data that is ignored by the human visual [15].

When an image is SVD transformed, it is not compressed, but the data take a form in which the first singular value has a great amount of the image information. With this, a few singular values can be used to represent the image with little differences from the original. The SVD image compression process is:

$$A = USV^T = \sum_{i=1}^{r} \sigma_i\, u_i\, v_i^T \quad (5)$$

Where, A can be represented by the outer product expansion:

$$A = \sigma_1\, u_1\, v_1^T + \sigma_2\, u_2\, v_2^T + \cdots + \sigma_r\, u_r\, v_r^T \quad (6)$$

When compressing the image, the sum is not performed to the very last SVs, the SVs with small enough values are dropped. (Remember that the SVs are ordered on the diagonal.)
The closet matrix of rank *k* is obtained by truncating those sums after the first *k* terms:

$$A_k = \sigma_1\, u_1\, v_1^T + \sigma_2\, u_2\, v_2^T + \cdots + \sigma_k\, u_k\, v_k^T \quad (7)$$

The total storage for *Ak* will be

$$K(m + n + 1) \quad (8)$$

4 Neuro-Fuzzy Singular Value Decomposition (NFSVD)

Data verity and the need of thinking system capable of recognizing the demand safety worker's wears leads to fellow intelligent paths for the forward and backward. We applied backpropagation to compute the derivatives required for learning without incurring a huge memory cost. These intelligent paths have the ability to identify, adaptive, and memorize the data. A neural-fuzzy network is important to deal with interim data via the implicit of some internal memories. Neuro-Fuzzy network aims to provide the fuzzy systems with automatic tuning ability. A color image has three components, red, green, and blue, each of these is defined by a matrix. Singular value decomposition (SVD) can be used to compress images. SVD reduces the matrix into a smaller and invertible square matrix,

The proposed network of NFSVD is five layers including intelligent recurrent layer (IRL), recurrent neural network RNN shares weights between time-steps. Therefore, we proposed RNN with image processing. Campaign SVD with NF is very important to speed up the image process especially we are dealing with online image recognition system. In this paper a proposed Neuro-Fuzzy Recurrent Neuro-Fuzzy Inference network NFRNFIT was used as intelligent recurrent layer as shown in Fig.2. The modelling of the proposed topology IRL was done depending on the same construction of Neuro-Fuzzy technique (layer1, 2, 3 and 4). The output decisions of layer 4 were taken out depending on the intelligent output of the feedback paths to specify all the values of the sub band for the image. We found that the system has the ability to be more accurate. The accurate intelligent output of the feedback paths led to reduce the number of iterations which makes the neuro-fuzzy system faster. The memory built inside the recurrent baths to increase the speed and accuracy of the process.

The proposed technique utilizes the HSV color space where the RGB color has a limitation to response to shading and fast illumination varying. RGB will be converted into HSV color space. The Hue H which represents group of color such as red, blue, and green or yellow will be adjusted. Next step is to improve the vitality of the S by applying AHE. The next step is to enhance the brightness of the V, apply the SVD, reduce the rank and use the NFSVD to reconstruct the demand areas. The final stage is to invert the image again to RGB and find the demand color (yellow) as shown in Fig.1.

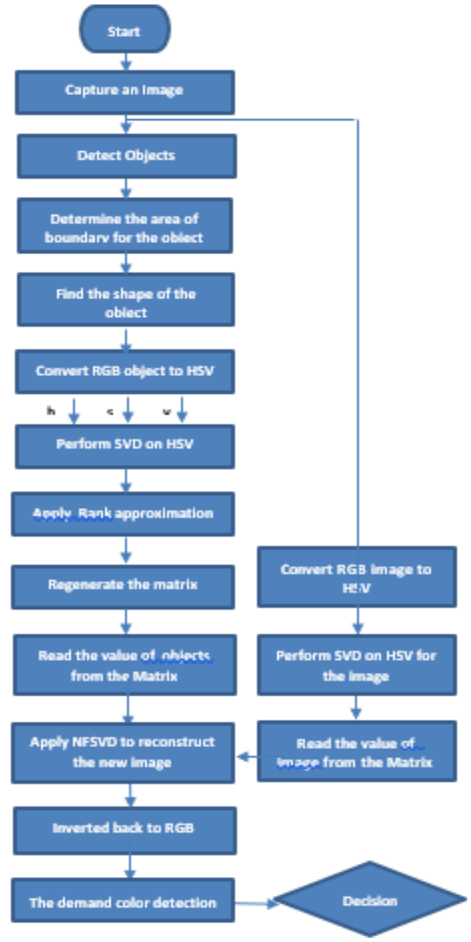

Fig. 1: NFSVD Architecture Flowchart.

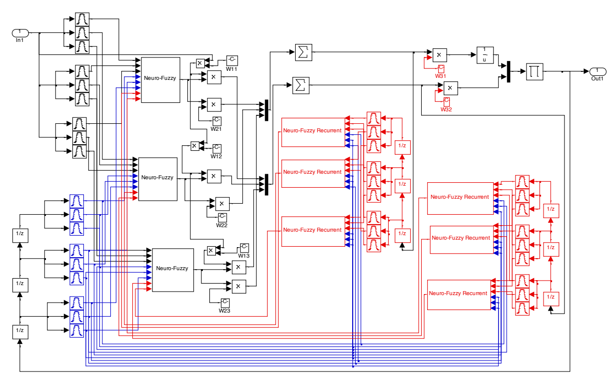

Fig. 2: Neuro-Fuzzy Recurrent Neuro-Fuzzy Inference Network (NFRNFIT)

5 Simulation and Implementation

The first step that we started with was testing the structure of Neuro-Fuzzy Recurrent Neuro-Fuzzy Inference Technique (NFRNFIT). So, we used MATLAB Simulink to do that as shown in Fig. 2

After we satisfied with the results obtained from NFRNFIT, the next step was to start image processing and recognition using NFSVD technique. There are some constrains that have to be considered:

1. Using five cameras with different plans and levels (Straight, up and behind) to get 3D image recognition. The precedence technique will be performed through these cameras.

2. Using four mono-color cameras for object detection to speed up the image processing, and one color-camera for color detection.
3. Using motion detection sensor for start-end and counting.
4. Using a frame to install all the sensors as shown in Fig. 3.
5. Using metal sensors to sense the safety shoes.
6. Using a reflecting stickers tape to stick on the helmet, vest and safety shoes as shown in Fig. 4
7. The best and efficient way to implement this technique is by using a container. In the sites, container is one of the most reliable cabins that can easily transported and shipped. In addition to that, it is cheap if compared to other alternatives.

(a)

(b)

Fig. 3: Intelligent Safety Frame for Construction (a) 3D Design (b) Implemented Frame.

Fig. 4: Safety Shoes a) with Stickers b) without Stickers.

There are two important criteria for color feature detectors are [32]:
1. (repeatability) they should be invariant (stable) under varying viewing conditions, such as illumination, shading, and highlights;
2. (distinctiveness) they should have high discriminative power.
Due to a real time process it gets an input as a number of frames and processing it simultaneously. In this color recognition process primary colors are segmented from the input RGB frame. Then each segmented color is identified by its own pixel. Therefore, the real-time color recognition has two major processes; Color segmentation and Color recognition [33].

5.1 Without NFSVD Technique

In the beginning, when we tried to detect the vest color (yellow), the first big issue that we faced was the skin color and the illumination as shown in Fig.5. The image processing program done by us couldn't recognize between the skin, shoes color and the vest color. So, the idea now is how to recognize and detect the yellow shapes color with different chromatic gradient. In the same time how can we enclose the whole chromatic gradient for the yellow color vests, specially there are different yellow colors for the vest with different illumination as shown in Fig.6. And 7

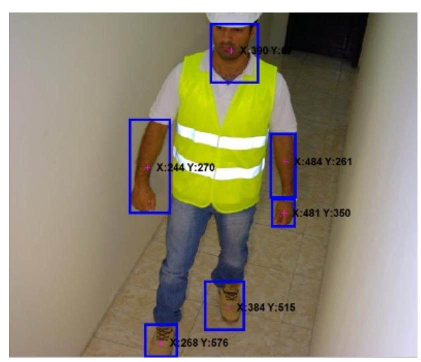

Fig. 5: Colour detection (yellow).

Fig. 6: Different illuminations.

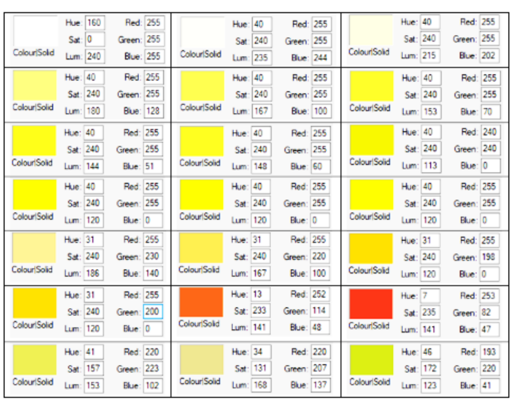

Fig. 7: different colours with different chromatic gradient.

The red threshold for the skin color lies between [0.08-0.17]. By setting the red threshold = 0.08 and the green threshold = 0.025, no need for the blue threshold as yellow color is mainly contributed by red & green color. The result still unsatisfied see Fig.8.

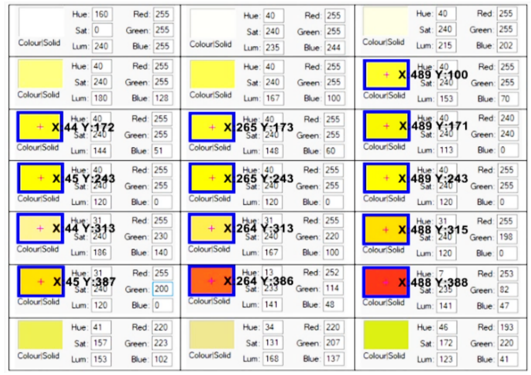

Fig. 8: Unsatisfied yellow Detection.

So, the idea now is to detect the vest color and eliminate the skin color how matter its chromatic gradient.

5.2 Applying SVD Technique without NF

There are two trends either converting the RGB image to a gray image and then controlling the SVD rank of the gray image or by applying SVD for each R, G, and B color separately and then control the rank for each one.

We applied tens of testing followed the both trends by changing the SVD rank with different values we found a difficulty to detect a certain yellow color. This lead us concluded that the SVD with RGB color image technique couldn't reach the demand because SVD does not supports RGB compression as shown in Fig. 9. And Fig. 10.

Fig. 9: Failure yellow detection.

5.3 Applying NFSVD Technique

The third stage of this scheme represents the proposed technique where the RGB colour was converted into HSV as illustrated in Fig.11, H was adjusted, improved the vitality of the S by applying AHE. The next step has been done by enhancing the brightness of the V, applying the SVD, reduced the rank and used the NFSVD to reconstruct the demand areas. The final stage is to invert the image again to RGB and find the demand colour (yellow) as shown in Fig.12.

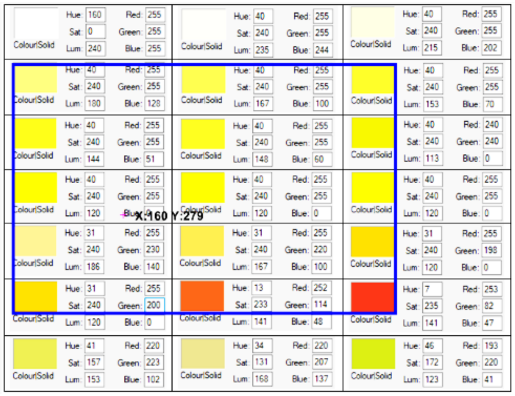

Fig. 10: Failure yellow detection.

Fig. 11: RGB colour to HSV.

Fig. 12: Result after applying NFSVD method.

6 Conclusions

A new image recognition approach NFSVD has been proposed in this paper. Novel contributions have been brought in both construction safety and image processing and recognition by using NFSVD. The new methodology provides online recognition and prevent worker's injury. Many experiments have been performed, the technique demonstrated the robustness and reliability of this methodology for safety in the construction field.

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