# *Hardware Co-Simulation of Skin Burn Image Analysis*


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***Abstract* — In this paper, a new method to automatically detect and categorize the severity of skin burns using image processing is presented. A database comprising skin burn images belonging to patients of diverse ethnicity, gender and age are considered. First the images are preprocessed and then classified utilizing the pattern recognition techniques: Template Matching (TM), nearest neighbor classifier (kNN) and Support Vector Machine (SVM). The classifier is trained for different skin burn grades using pre-labeled images and optimized. The complete model encompassing a reconfigurable image filter is developed using model based approach of Xilinx system generator tool. Hardware complexity and timing constraints are optimized to vertex-4 board. This system developed works as an automatic skin burn wound analyzer, aids in the diagnosis and study purposes as well.**



***Keywords: kNN; SVM; System Generator***


## I. INTORDUCTION

Burn injury is one of the major accidents and life threatening causes in the modern world. When a person meets with a burn accident the skin layers get affected. Doctors determine the degree of burns by examining which layer and organs are affected and suggest treatment. The work proposed here focuses on automating this process. A digital camera is used to capture the burn images of the patient and the software developed would analyze the image. Using the outcome of this research, severity of injury can be estimated, and the depth of the injured tissue can be quantified.

## II. OVERVIEW

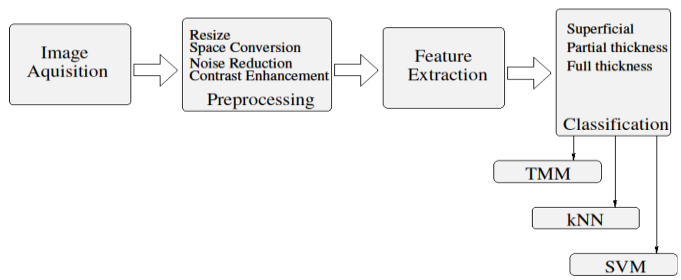


Figure 1.1: Overview of the work

Prior to the image processing for analyzing the wound, medical images of skin burns are collected from open source database of images and also from the burn ward of some hospitals. The images are digital and color. In order to assess the progress of healing of wound, a series of images of wound subjected for medication and palliative care were acquired. A data base of such images with substantial number was constructed to validate the outcome of this work. The general and clinical details of the subjects such as gender, age, ethnicity, treatment history, cause and type of burn and experts opinion will be collected for each image.

General image processing and enhancement algorithms applicable to wound characterization will be applied in this work on medical skin burn images. Usual flow of computer based processing begins with image acquisition, noise removal, contrast enhancement, feature extraction from the Red, Green and Blue components such as variance, mean, hue, saturation, intensity, texture, shape and area. As there are no invasive techniques to assess the nature of the wound, computerized techniques are proposed as a cost effective solution. An expert looks at the color of the image, texture, area and tissue of the wound. Computer based pattern recognition methodology like TM, kNN and SVM classifiers mimic the way an expert collates the information to arrive at a decision [1, 2].

The automatic wound analyzer will be useful at remote locations where medical experts are not available and also at the time of major burn accidents. This can serve as a good teaching and research tool for students of health care and aid in the follow up and further pathology for the burns. The proposed system will be built and optimized such that it will use little computational resources, power and computes faster.

The proposed algorithm software is first developed on the Matlab with the help of Image Processing toolbox to enhance and pre process the raw images. The enhanced images are classified based on the severity of the burn with pattern recognition techniques later the algorithm model is developed using Xilinx System Generator tool. The hardware complexity and timing requirements are measured by co-simulating the modes with vertex-4 board.

## III. BURN INJURIES

For successful evolution of a bun injury it is essential to initiate the apt correct first treatment. To choose the apt one, it is necessary to know the depth of the burn, and a fine visual assessment of burn depth which highly requires specialized dermatological expertise. As the cost of maintaining a burn unit is very high, it would be desirable to have an automatic system to give a first assessment in all the local medical centers where there is a lack of specialists.

Two important factors in determining how bad a burn is include how hot the skin gets and how long the burn lasts. The location is also important because skin varies in thickness, water and oil content, the amount of subcutaneous fat, and the number of blood vessels from one location in the body to another [3].

### *A. Diagnosing a burn injury*

The seriousness of a burn injury depends on how deep the injury is and how much the body has been burned. It is common for a person with a large burn injury to have burn of different depths. The deepest injury is usually at the center of the burned area. There are a number of tests used to determine the depth of a burn injury, but an experienced burn specialist's examination continues to be the most reliable way of evaluation the depth of burns. A potentially dangerous condition that some bun victims get into is damage to pulmonary system so they can't breathe. Inhalation injury is the most common cause of death in burn victims. Flash buns often harm the face but rarely involve the airway, unlike severe burns from prolonged heat exposure associated with smoke inhalation.

Table 3.1 Skin burn characteristics

| Type of Burn | Blistering | Appearance | Pinprick test |
|---|---|---|---|
| **Superficial dermal** | Present | Bright red | Sensitive to pain |
| **Partial thickness** | Blisters are broken | Cream colored | Dullness to pain |
| **Full thickness** | Absent | Gray/White | No sensation |

## IV. CLASSIFICATION OF BURN IMAGES

Once the skin burn images are enhanced, next step is to label these images as a specialist does for the proper medication. This forms the crucial part of this work. Based on the color and the depth of the burn including the area of the burn, skin burns are classified into three categories by extracting the features of the burn image and training the classifiers accordingly [4].

### *A. Feature Extraction*

Feature selection is the very important factor while classifying the images into different categories. The selected features represent the characters of the images belonging to particular category. Since the color of the skin burn images differs based on the depth of the wound, the color features of each image are extracted and used for he classifier training.

In this work, firstly the image is re-sized to *90*90* pixels, secondly RGB space is converted into *L*a*b** color space. After pre processing of the image, the *V1* chrominance plane of the *L*a*b** color space is selected for feature extraction. Further a *90*90* image is subdivided into *9*9* blocks and the features like *mean* and *(2, 1)* $^{th}$ coefficient of Discrete Cosine Transform (DCT) function chosen to train classifiers. The two dimensional DCT equation is given by

$$X(k_1 k_2) = \frac{4\in_{k1}\in_{k2}}{N^2}\sum_{n_1=0}^{N_1-1}\sum_{n_2=0}^{N_2-1} x(n_1,n_2)cos\left(\frac{\pi(2n_1+1)k_1}{2N_1}\right)cos\left(\frac{\pi(2n_2+1)k_2}{2N_2}\right)$$

$$\text{where}\quad \begin{cases}\in_k = \dfrac{1}{\sqrt{2}} & \text{for } k=0\\ \quad\;\; = 1 & \text{otherwise}\end{cases}$$

$$\text{and}\quad k = 0,1,2,\ldots\ldots,N$$

## V. SYSTEM GENERATOR

System Generator is a Digital Signal Processing (DSP) design tool from Xilinx that enables the use of the Mathworks model based Simulink design environment for FPGA design. Designs are captured in the DSP friendly Simulink modeling environment using a Xilinx specific blockset. These blockset include the common DSP building blocks such as adders, multipliers and registers, also a set of complex DSP blocks such as FFTs, filters and memories are present. These blocks are used in our design to implement Image Processing algorithms [5].

### *A. SysGen Design Flow*

Figure 5.1 shows the design flow of the hardware implementation of a DSP algorithm. Steps involved in design implementation are:

- Algorithm development in Matlab.
- Modeling the algorithm using model based design approach with the help of Simulink and System Generator blocks.
- Code generation for the Model developed.
- Implementation of the design, within Xilinx design environment.

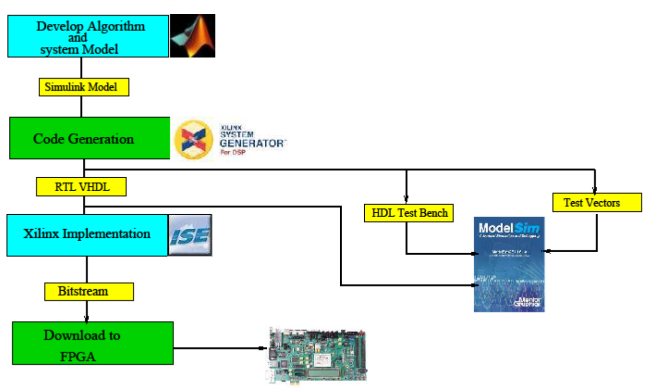


Figure 5.1: SysGen Design Flow

The hardware co-simulation and verification of the algorithm is developed using Simulink, System Generator and Xilinx Simulation tools. The model is verified by co-simulating the design requirement and the timing constraints are determined.

### *B. Reconfigurable Image Filter Design*

The image filter designed is configured to process a *256*256* color image. Nine different 2-D filters can be configured. The filter can be selected by changing the mask parameters stored in the ROM block.

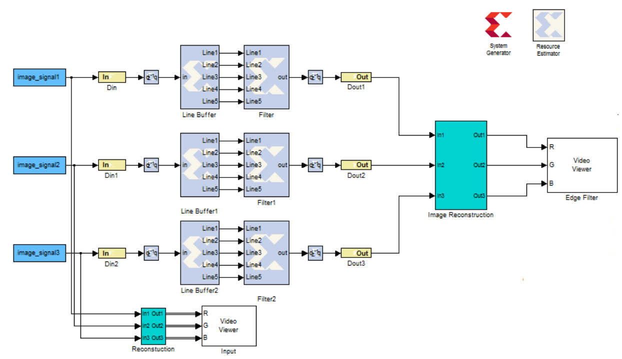

Figure 5.2: Reconfigurable Filter

Figure 5.2 shows the reconfigurable filter model in which firstly, the image is converted into a vector of intensity values in Matlab and this series of vector is passed into the Xilinx blocks for processing. The buffer block here stores the intensity values, later these intensity values are used to perform filter operation, the filter coefficients are previously derived and stored in the block ROM, depending on the filter chosen the values are selected. Once the processing is done within the Xilinx block set, the intensity values are taken back to MATLAB and reconstructed.

### *C. Filter and Classification Model Design*

The processing unit mainly consists of three sections as follows:

- Address Generator Unit: Preprocessed image pixels in the form of a vector will be stored in the ROM block. The address generator unit generates the address of the image pixels those have to be processed. In this work *n8* neighbors are selected to remove impulse noise in the image and to classify the burn grade accordingly [3].
- Memory Unit: A *256*256* image is preprocessed in Matlab and converted into 1-D vector and stored in ROM for processing.
- Operation Unit: Actual pixel processing takes place in this block. It accepts the pixels from the address

generated by address generator and performs manipulations.

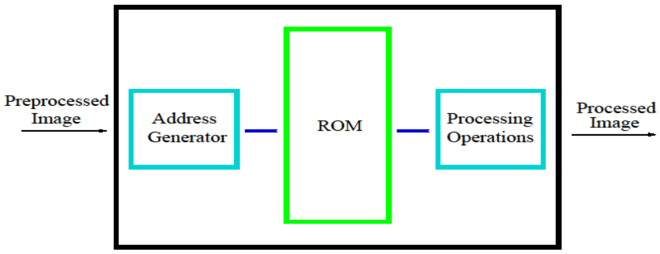


Figure 5.3: Processing Unit

Here the impulse filter operation is done by averaging the *n8* pixels as shown in the Figure 5.4. Whenever there is an error hit, averaging of *n8* pixels takes place and the classification is performed based on the stored templates.

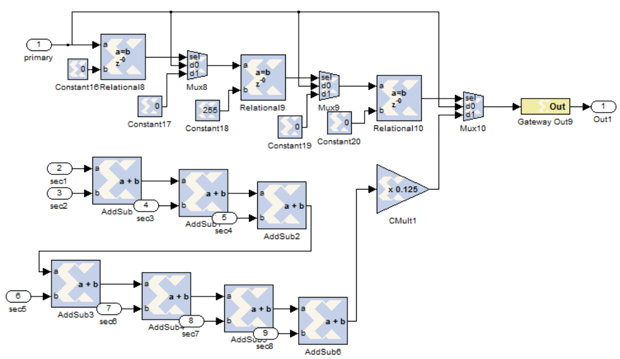

Figure 5.4: Impulse Filter

## VI. RESULTS

Acquisition of the skin burn images is done by ordinary camera which can be found in basic mobile phones or a laptop web-cam and the images used are captured in usual ambiance without any particular lighting condition or isolation this makes our work user-friendly. Images acquired in these conditions are noisy due to poor illumination, lack of dynamic range and wrong setting of the lens aperture and also may be due to environment conditions. Hence enhancement of these images before categorizing into various grades is necessary and vital.

### *A. Database*

Our database consists of 120 images, 40 images from each grade are collected from various sources like internet, personally captured from Hospitals and scanned. All images are set to standard jpeg format and used in this work.

Table 6.1: Database of Burn Images

| **Type** | **No. of Images** | **Internet** | **Captured** | **Scanned form books** |
|---|---|---|---|---|
| **Grade1** | 40 | 8 | 27 | 5 |
| **Grade2** | 40 | 7 | 28 | 5 |
| **Grade3** | 40 | 4 | 32 | 4 |

### *B. Image Classification*

Figure 6.1 shows the chrominance plot of features, *mean* and *DCT* values of 120 skin burn images belonging to 3 different categories. Features of 40 images belonging to each category are plotted. *(2,1)*$^{th}$ coefficient of DCT values are plotted on x-axis and chrominance mean on y-axis. The distribution of these features allows the classifiers to learn and discriminate the test sample values into different category.

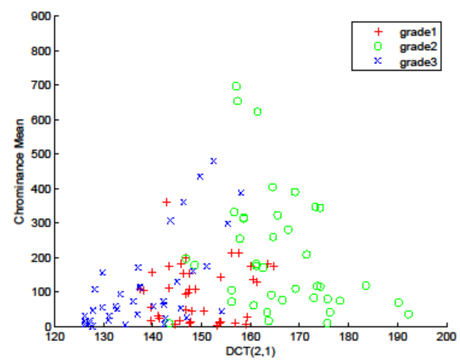


Figure 6.1: Feature Space

- Template Matching Method: In this method of classification, a new test vector containing mean and DCT values of sample images is matched with the previously stored templates belonging to different grades. Depending on the closeness of the match, test sample is categorized. Testing of 120 images, with 40 images from each category is carried out. 20 images from each category are used for training and remaining 20 for testing with cross validation. Overall a classifier efficiency of 66% is incurred with this method.

- kNN Classifier: In this method, classification is based on nearest neighbor method. Depending on the value of the *k* specified, algorithm checks for the k nearest neighbors of training values, surrounding a test value. The majority of the test values determine the class of test value. In this work, multi class kNN classifier is used with *k* value as 3. Cross validation of training and testing vectors are carried out by using 3 fold techniques by randomly selecting training and testing vectors. This method has ensued with an efficiency of 75%.

- SVM Classifier: SVM is a binary classifier and the data are classified using support vectors. Separating hyperplane is crated based on the kernel function. Complexity varies accordingly with the kernel function. In our case for multi classification, one against all property is used by choosing quadratic kernel function. Binary classification result is plotted with 3 fold cross validation. SVM classifier has resulted with an efficiency of 90%.

Graphs below shows the binary classification results using one against all property for multi class classification. The graphs show training, classified and support vectors.

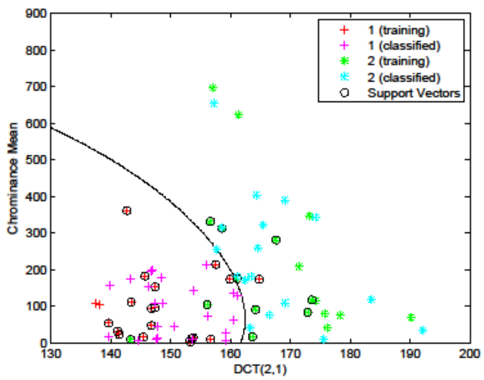


Figure 6.2: Classification of grade1 and grade2 features

From the graphs it can be observed that the plane separating the features belonging to different group. The points marked with the circles are the support vectors chosen by the kernel function for separation.

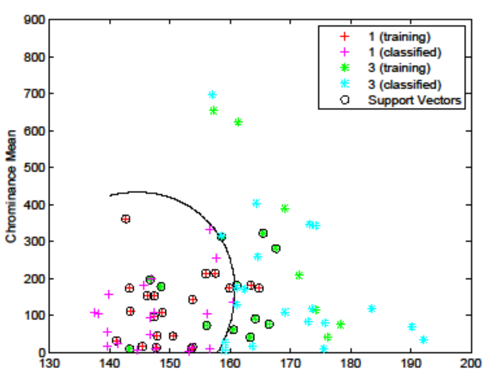


Figure 6.3: Classification of grade1 and grade3 features

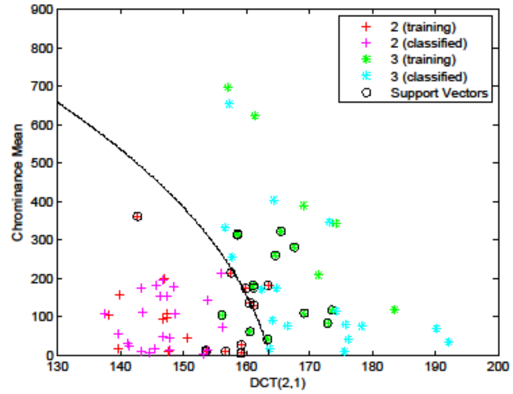


Figure 6.4: Classification of grade2 and grade3 features

## C. *Co-Simulation Results*

A reconfigurable image filter is constructed to implement spatial filters for image processing, this filter uses 5*5 window mask to perform filter operation. The filter constructed can be configured to perform filtering operations like *Edge filter, SobelX filter, SobelY filter, SobelXY filter, Gaussian filter, Smooth filter, Blur filter, Sharpen filter an Identity filter* depending on the filter coefficients chosen. The filer model is verified for a *256*256* color image configuring for each filter.

A model, to filter impulse noise and to classify the burn grade is designed and verified for color images of size *256*256* is shown in the Figure 6.5.

Figure 6.5: a) Original Image, b) Noisy Image and c) Filtered Image

Resource utilization on vertex-4 board for the models designed is tabulated below.

Table 6.1: Resource Utilization

| Components | Reconfigurable Filter | Classifier with Impulse filter |
|---|---|---|
| Slices | 1053 | 390 |
| Flip Flops | 1656 | 24 |
| Block RAM | 27 | 108 |
| LUTs | 1128 | 723 |
| IOBs | 48 | 399 |

## VII. CONCLUSION

Examination of the classifier results shows, that the performance of the classifier has improved from Template Matching to kNN and further to SVM method. Performance degradation is due to miss-classification of burn wounds. It has been noticed that even doctors having difference of opinion while classifying burn images. This is to be accepted, when a diverse database like ours is constructed from images belonging to people of different race, gender and age under differing ambient light. Very few papers, as cited in reference are available on this work, reporting results of those are on very specific and local database of images obtained under controlled conditions.

Filter models designed using System Generator have provided good performance with the resource utilized. And also the filter designed here is reconfigurable. It can be used for various image processing applications. The impulse filter results are considerable up to an added noise of 20%.

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