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Thermal Imaging in Surgical Site Infection (SSI) Detection

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Abstract - *Surgical site infection (SSI) is defined as infection occurring up to 30 days after surgery (or up to one year after surgery in patients) and affecting either the incision or deep tissue at the operation site. It results in prolonged hospitalization, increased morbidity, mortality and increased surgery related costs. Therefore, early detection and prediction is of mere importance. Since, most of the techniques are not accurate and invasive, it is necessary to overcome the limitations of such studies. Thermography is a non-invasive, non-contact tool that uses the heat from our body to aid in making diagnosis of health care conditions. To overcome these limitations of previous studies to detect and predict surgical site infections the use of thermal imaging becomes necessary. This study proposes the use of thermal imaging on surgical site infections in abdominal surgeries by bringing about temperature and statistical analysis to help predict surgical site infections at an early stage. It is found that the temperature at the infection site is less comparatively less than the normal body temperature. Thus thermography is an effective method to evaluate the surgical site infection at an earlier stage. Image fusion techniques are used to get more informative images for further applications.*

Key Words: Thermography, Image Processing, ROI, REASEARCH IR SOFTWARE, Segmentation, Contrast, Homogeneity, Kurtosis.

1. INTRODUCTION

1.1 Background

Surgical site infections are infections that occur after surgery. They can be infections involving just the skin or deeper tissues and organs. Symptoms might include redness and pain around the area of surgery, drainage of puss or cloudy fluid, fever etc. Most predominantly visible surgical site infections are seen in abdominal surgeries. Abdominal surgeries have high rates of surgical site infections (SSIs), contributing to increased morbidity and mortality and costs for hospitalization, therefore the Thermography is completely safe and uses no radiation. It can bring about a temperature variation in the image that is being captured.

To overcome the limitations of previous studies and yet detect and predict surgical site infections the use of thermal imaging becomes necessary. This study proposes the use of thermal imaging on surgical site infections in abdominal surgeries by bringing about temperature and statistical analysis to help predict surgical site infections at an early stage. Thermal and digital images of the Surgical site are captured. At the region of surgical site infection there are variations in surface body temperature compared to the normal body temperature. These variations can be analyzed using the thermal images by two methods, image processing and statistical analysis. Image processing uses filtering, segmentation methods, feature extraction for the evaluation of the wound.

1.2 Problem Statement

Existing modalities includes surveillance method, patient interactions and evaluating the medical history which causes the less accuracy. The Studies based on the direct observation of wound by health professional has done, the disadvantage being that interpretation may not always be right. Abdominal surgery is a classification of surgical procedures performed in the abdominal region to treat or diagnose the medical conditions. This involves different types of techniques depending on which abdominal organ is involved that is liver, kidney and stomach. These procedures requires the opening of the abdomen with the large incision and referred to as laparotomies or abdominal surgeries.

1.3 Objectives

1. To generate thermal and digital image database of abdominal surgical sites.
2. To carryout statistical analysis using Research IR and MATLAB softwares.
3. To identify prominent feature, which can be used to detect the on site of infection at the earliest.

2. LITERATURE REVIEW

Sudarvizhi D, Kaavyaa A, Nandini N, Lakshmi priya K[1] Described how The wound image is captured and the noise is removed using different types of filters. The ROI image from background is separated by image segmentation is used for dividing an image into different textures on the image. Region growing, edge detection and Gabor filter algorithm are used to perform segmentation.

Snehalatha umapathy, Sowmya v, Anburajan Mariamichael[2] Described how The K-means algorithm was used for image segmentation. From the output segmented image the features are extracted using the gray-level co- occurrence matrix method.

K. Sundeep Kumar and B. Eswara Reddy[3] Described how The first task is to assess the wound and capture the wound images by photographic wound assessment tool(PWAT). segmentation is done for the area of wound using denoising techniques. Used wound image analysis classifier to classify the wound images.

Renu Bala[4] Descibed how Several methods of texture feature extraction such as structural based method, statistical based methods, transformation methods are used to find first order,second order and higher order statistics are obtained.

R. Johnson Suthakar, J.Monica Esther, D. Annapoorani, F. Richard Singh Samuel[5] Descibed how different fusion techniques such as pixel-level, feature level and decision level. The fused image provides detail information about the region which is useful to perform image processing, segmentation and feature extraction.

3. METHODOLOGY

1. The subject will be briefed about the test and provide consent on the consent form.

2. At room temperature and ambient relative humidity level dressing shall opened, with wound well exposed, on days as per surgeons' protocol for wound management.

3. The wound would be exposed for 5 minutes to attain thermal equilibrium with room temperature. After the acclimatization time, the thermal images and digital images of the wound are acquired while the subject is lying on the bed.

4. The images will be subjected to detailed statistical analysis and image processing.

3.1 Data Collection

The first step involves the collection of the data. The data was acquired from Pavan clinic, Hoolageri. Our study involves 6 subjects of which two of the subjects do not have the occurrence of infection. A total of 6 digital images and thermal images of the surgical site of the patient are captured with the aid of the thermal camera. During this process the room temperature and the humidity of the surrounding is also noted.

The collected thermal images are loaded to the Software Research IR- which is camera specific. This software helps in analysis of the thermal image.

REASEARCH IR SOFTWARE: Research IR is a powerful and easy to use thermal analysis software package for FLIR Science Cameras.

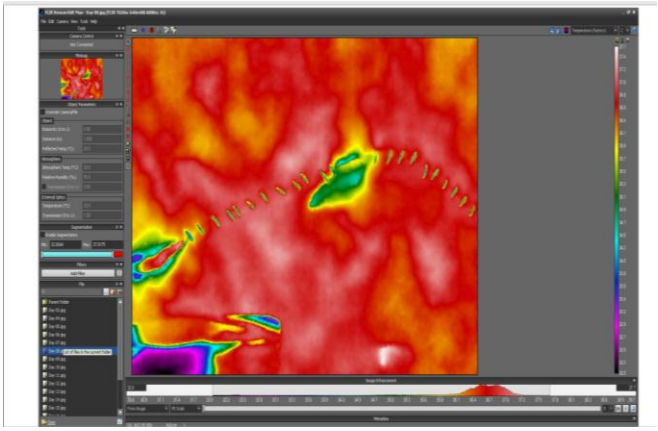


Fig -1: Screenshot of Research IR Software

Temperature analysis involves the following steps:

1. Load the image to the software.

2. Select a palette according to the requirement.

3. Input the humidity and room temperature corresponding to that image.

4. Adjust the temperature scale based on the minimum and maximum temperature of the image.

5. After these adjustments select 4 regions:- two infected and two non-infected referring to the digital images.

6. Using analysis toolbox the mean temperature minimum temperature and maximum temperature of the regions are found.

7. These values are noted in excel sheets and graphs are plotted for easy interpretation.

3.2 Image Processing in Matlab

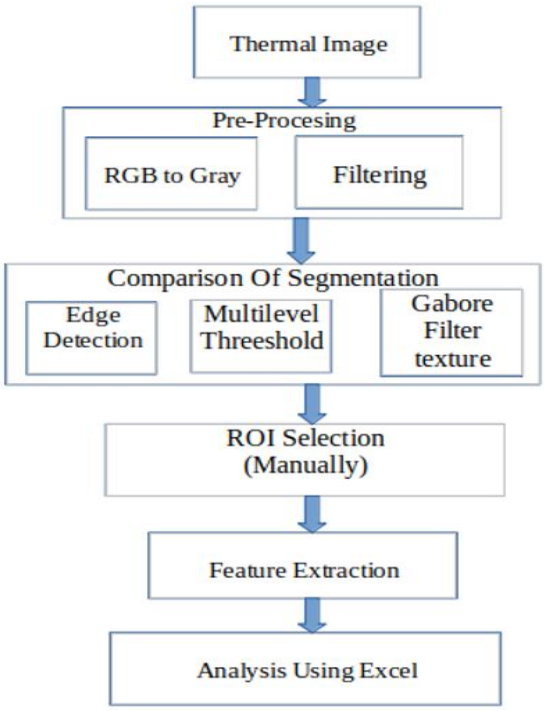


Fig- 2: Thermal image processing flowchart

Thermal image is basically the temperature mapping of the body. It shows the differences in the surface temperature using a color palette. The processing is done as follows:

1. *Load the thermal image*.

   The thermal image is read in software MATLAB 2018a.

2. *Preprocessing techniques:*

   This step involves RGB to gray conversion and filtering of the gray scale image is done considering 5 types of filters namely-

- Gaussian Filter: A Gaussian filter is a linear filter. It's usually used to blur the image or to reduce noise.
- Weiner Filter: It removes the additive noise and inverts the blurring simultaneously. The Wiener filtering is optimal in terms of the mean square error. In other words, it minimizes the overall mean square error in the process of inverse filtering and noise smoothing.
- Median: It is a non-linear filter used to remove noise.
- Box: It is basically an average of surrounding pixel kind of image filtering.
- Guided filter: It is an edge-preserving smoothing on an image, using the content of a second image.

The validation of filters is done by calculating the PSNR and SNR of the images wrt the original image. The filter obtaining the highest values is considered for further processing. Here GAUSSIAN FILTER is taken. When working with images we need to use the two dimensional Gaussian function. The Gaussian filter works by using 2D as a point-spread distribution functionality. This is achieved by convolving the 2D Gaussian distribution function with the image. The Gaussian filter is a non-uniform low pass filter. The kernel coefficients diminish with increasing distance from the kernel's centre. Central pixels have a better weighting than those on the periphery. Larger values of σ produce a wider peak (greater blurring). Kernel size must increase with increasing σ to take care of the Gaussian nature of the filter. Gaussian kernel coefficients rely on the value of σ. At the edge of the mask, coefficients must be near 0.

3. *Segmentation of the Filtered image:*

   Segmentation methods such as

- Edge detection (Sobel): is a technique used for finding the boundaries of objects within images.
- Multilevel thresholding: segments the gray level image into several distinct regions taking more than one threshold.
- Gabor filter texture based segmentation: partition of the image into regions based on their texture.

All these methods are validated using the following parameters:

- Dice co-efficient: also known as Sorensen-Dice index is a statistical tool which measures the similarity between two sets of data.
- Jaccard index: is a statistic used for gauging the similarity and diversity of sample sets.
- Structural similarity index: perceptual metric that quantifies image quality degradation which requires 2images from same image capture.

Results with automated and manual segmented images were compared in which it showed no significant differences, hence automated segmentation was not considered.

4. *ROI (region of interest):*

   ROI selection is done manually by selecting 6 regions, two infected, two non- infected and two skin regions referring to the corresponding digital image.

5. *Feature extraction:*

   Once the ROI is selected Higher order statistical features like Contrast, Correlation, Homogeneity, Energy, Skewness, Kurtosis, Variance, Mean and Standard Deviation were extracted from those regions which are defined as follows-

- Contrast: Difference in luminance/color.
- Correlation: Statistical measure which indicates how two or more variables fluctuate.
- Homogeneity: Depends on intensity, same gray values meaning homogeneity same.
- Energy: It is mapped to brightness or intensity of image.
- Skewness: It is a measure of symmetry, or more precisely, the lack of symmetry.
- Kurtosis: Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution.
- Variance: measures how far a set of data is spread out. Variance is the average of the squared distances from each point to the mean.
- Mean: is most basic of all statistical measure. Means are often used in geometry and analysis.
- Standard Deviation: it shows how much variation or "dispersion" exists from the average.

4. RESULTS

4.1 Filtering

This is a pre-processing step in image processing which basically helps in removal of the noise.

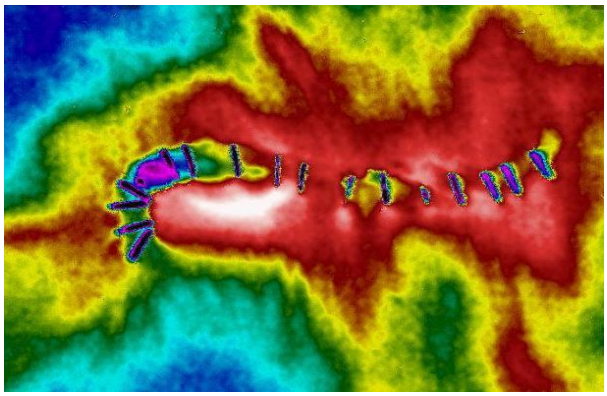


Fig-3: Unfiltered Thermal Image

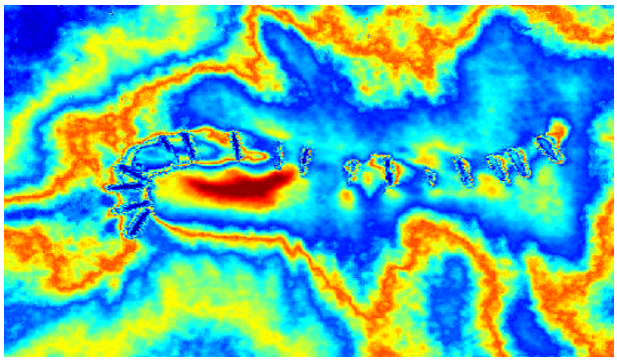


Fig-4: Filtered Thermal Image

Filtering is carried out by considering 5 filters and is compared using PSNR and SNR.

Table-1: Filter table of Thermal image

Filter	PSNR	SNR
Gaussian	98.2327	91.4025
Weiner	35.02846	28.21020
Median	29.98850	23.17025
Box	29.98860	23.17035
Guided	34.01	27.22171

For thermal image the Gaussian filter gives higher PSNR and SNR with sigma value of 0.265.

4.2 Segmentation Comparison

For the analysis of which segmentation gives the better results we considered 3 segmentation methods and evaluated them with a manually segmented image using the following parameters.

Table-2: Segmentation comparison of image

Segmentation	Dice Index	Jaccard Index	Structural Similarity
Edge Detection	0.046	0.4478581	0.023643
Multilevel Threeshold	0.999	0.4478582	0.999975
Gabor texture segmentation	0.436	0.5834246	0.279565

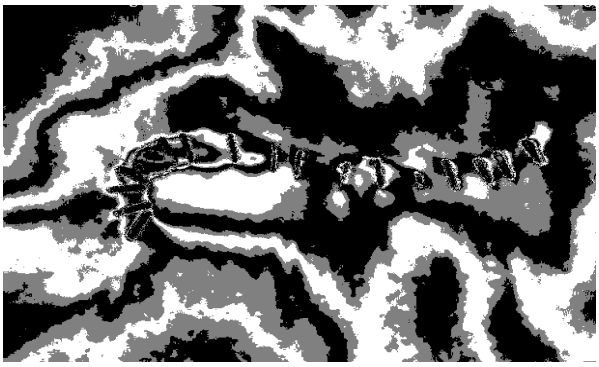
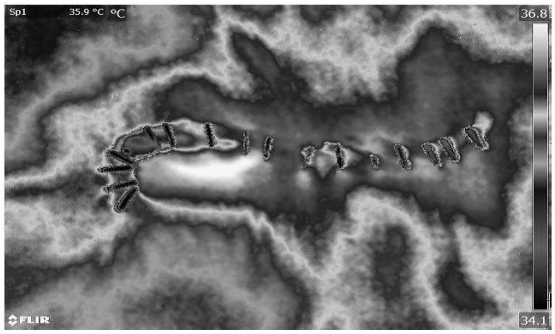


Fig-5: Multilevel Thresholding

4.3 Manual Segmentation

The ROI - 2 non infected, 2 regions outside SSI and all infected regions are manually segmented.

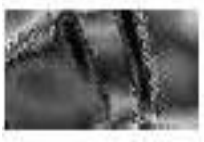


(a) Segmented image

(b)Non infected region1

(c)Non infected region2

(d)Infected region1

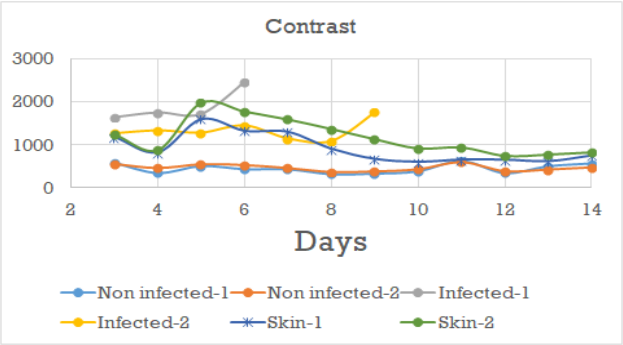


(e)Infected region2

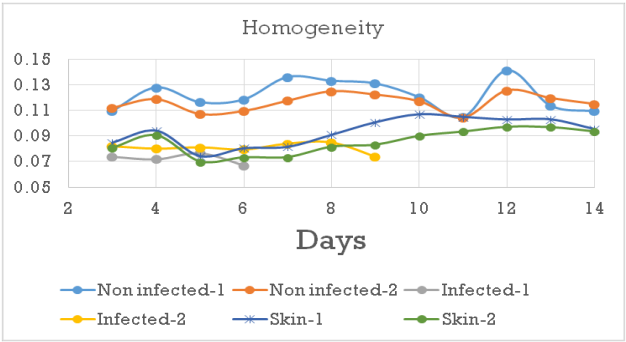
Fig-6: Manually segmented images

4.4 Analysis of the Image

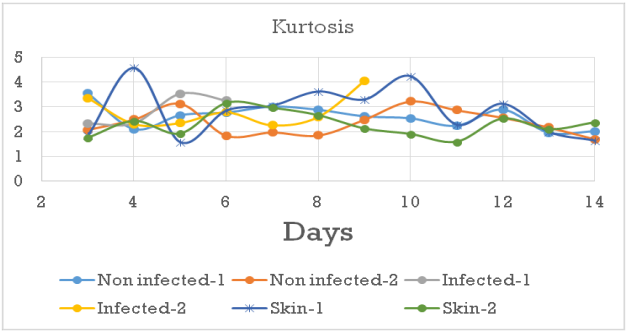
Graphs of the parameters were plotted and analyzed. It's seen that Contrast, Homogeneity, Mean and Kurtosis shows significant variations compared to other features. Hence they are taken for analysis.



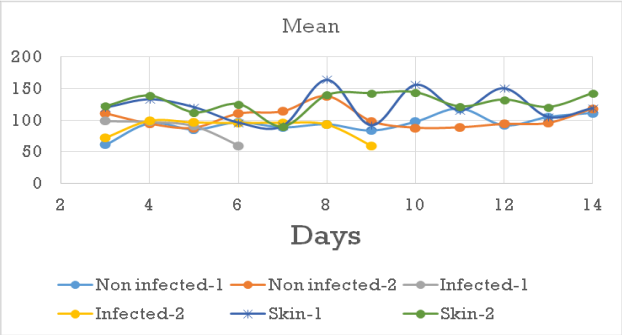
Chart– 1: Representing contrast of thermal image.



Chart– 2: Representing homogeneity of thermal image.



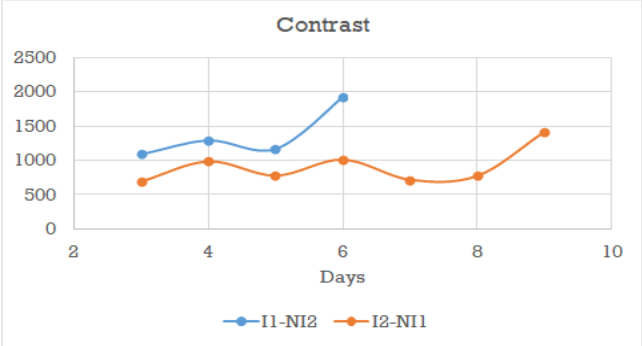
Chart– 3: Representing kurtosis of thermal image.



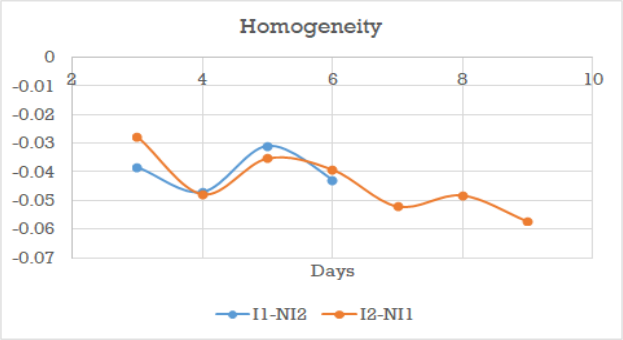
Chart– 4: Representing mean of thermal image.

4.5 Difference Graphs of Thermal Image

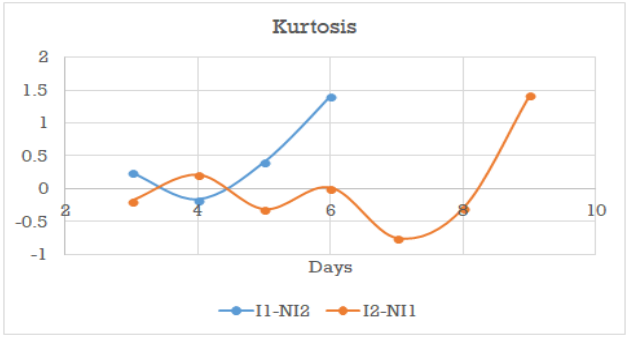
From the feature values the difference between the infected and nearest non-infected site were taken i.e I-NI. These values were plotted



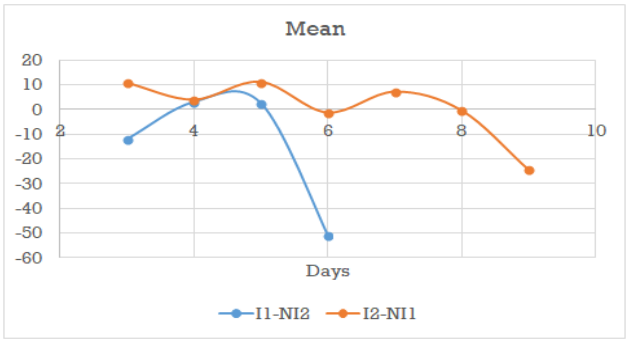
Chart– 5: Representing difference contrast of image.



Chart– 6: Representing difference homogeneity of image.



Chart– 7: Representing difference kurtosis of image.



Chart– 8: Representing difference mean of image.

5. CONCLUSION

The features were extracted and analyzed in excel sheet. Features which gave better results were taken. i.e Contrast, Homogeneity, Mean and Kurtosis. Variations in the graphs were observed. And difference between the infected and non infected site is taken. These difference graphs help in quantification of the wound. By this we can predict the infection at an earlier stage i.e before visible to naked eye.

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