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Automated Detection of Diabetic Foot Using Thermal Images by Neural Network Classifiers

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ABSTRACT
Diabetes is one of the major problems worldwide. It is a metabolic disease where the improper management of blood glucose level lead to the risk of many diseases like foot complications, amputation, kidney diseases etc. Early detection of diabetes and their precursors is essential in preventing their devastating consequences such as foot infection and amputation. There are various methods to diagnose diabetes which are invasive techniques. Infrared thermography is a promising modality for such a system from which diabetes is non-invasively detected using the thermal foot images. The temperature differences between corresponding areas on feet are the clinically significant parameters. The thermal images are preprocessed, segmented using k-means clustering and then the textural features (GLCM) are extracted and then classified using classifiers. In this paper, to diagnose diabetic foot, three models like Probabilistic Neural Network(PNN), K-nearest Neighbor Network(KNN), and Support vector machine(SVM) are described and their performances are compared. Experimental results show that KNN has an accuracy of 95.66 %. This infers that KNN model outperforms the other two models.
Keywords: *Infrared thermography, GLCM, probabilistic neural network, support vector machine, k nearest neighbor network.*

INTRODUCTION

Diabetes mellitus commonly referred as diabetes, characterized by high blood sugar levels over a prolonged period. It results due to absolute or relative deficiency of insulin. The lack of insulin affects the metabolism of the body. Diabetes is one of the major health care problem and continue to increase in population and significance. Diabetes is the seventh cause of mortality in the world.

SYMPTOMS

High blood sugar includes polyuria (frequent urination), polydipsia (increased thirst), polyph-agia (increased hunger). If un treated, diabetes can cause many complications such as blurry vision, headache, fatigue, slow healing of cuts, and itchy skin.

Acute complications can include diabetic ketoacidosis, nonketotic hyperosmolar coma, or death. Serious long term complications include heart diseases, stroke, chronic kidney failure, foot ulcers and damage to the eyes. Foot diseases are common complications of DM. If not adequately treated, the risk of amputation and mortality is increased.

TYPES OF DIABETES

Type I Diabetes

It is characterized by loss of the insulin producing beta cells of the islets of Langerhans in the pancreas, leading to insulin deficiency. The majority of type 1 diabetes is of the immune-mediated nature, in which a T-cell mediated autoimmune attack leads to the loss of beta cells and thus insulin. symptoms may develop rapidly

(weeks or months) in type 1 DM. The cause is unknown.

Causes of diabetes mellitus

Normally, the immune system protects the body from infection by identifying and destroying bacteria, viruses, and other potentially harmful foreign substances. But in autoimmune diseases, the immune system attacks the body's own cells.

Symptoms of the disease usually develop over a short period of time. Diabetes mellitus can appear at any age.

GENETIC SUSCEPTIBILITY

Heredity plays an important part in determining who is likely to developdiabetes. Genes carry instructions for making proteins that are needed for the body's cells to function. Many genes, as well as interactions among genes, are thought to influence susceptibility to and protection from type 1 diabetes. Variations in genes that affect more than 1 percent of a population group are called gene variants.

Type II Diabetes

It is characterized by insulin resistance, which may be combined with relatively reduced insulin secretion. The defective responsiveness of body tissues to insulin is believed to involve the insulin receptor. Diabetes mellitus cases due to a known defect are classified separately.

Type II diabetes patients have an elevated risk of plantar ulcerations compare to normal population. The gradual loss of nerve function limits the amount of sensation on the plantar aspects of feet. Decrease in this sensation level disables DM individuals from being able to feel theonset of injury to the feet.

RISK FACTORS FOR TYPE II DIABETES

People who develop type 2 diabetes are more likely to have the following characteristics:

- Age 45 or older
- Overweight or obese
- Physically inactive
- Parent or sibling with diabetes
- History of giving birth to a baby weighing more than 9 pounds.

Gestational Diabetes

Gestational diabetes develops in some women when they are pregnant. This type of diabetes goes away after the baby is born. However, if the person had gestational diabetes, she will have a greater chance of developing type 2 diabetes later in life.

THERMOGRAPHY

Thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers or 9–14 μm) and produce images of that radiation, called thermograms. Since infrared radiation is emitted by all objects with a temperature above absolute zero, thermography makes it possible to see one's environment with or without visible illumination. Therefore, thermography allows one to see variations in temperature. Humans and other warm-blooded animals become easily visible against the environment, day or night.

Thermography is a non-invasive, non- contact tool that uses the heat from your body to aid in making diagnosis of a host of health care conditions. Thermography is completely safe and uses no radiation. The image is shown in fig. 1.1.

This equipment usually has two parts, the IR camera and a standard PC or laptop computer shown in fig 1.2.

The system measure temperature ranging from 10-55 deg Celsius to an accuracy of 0.1 deg Celsius. Thermal imaging system are an economical easy to use tool for examining and monitoring patients quickly and accurately. The heat from the body is processed and recorded in the computer into an image map which can then be analyzed on screen. A doctor can use the image map to determine if abnormal hot or cold areas are present.

Fig.1.1

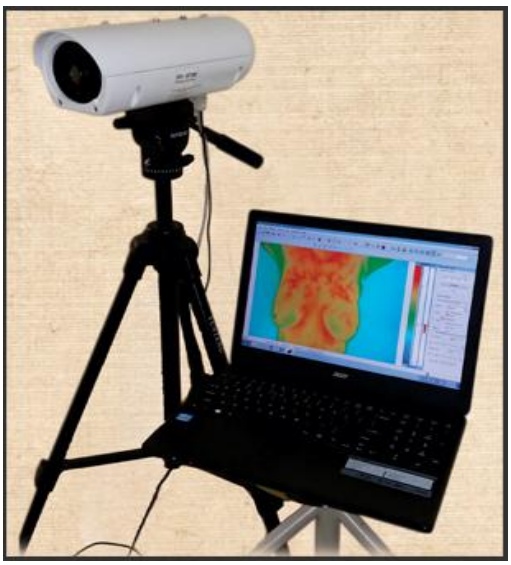


Fig.1.2

AUTOMATED DETECTION SYSYTEM

Automated diabetes foot detection system consists of four stages. Fig 1.5 shows the block diagram of Diabetes foot detection system. First stage is to pre-process the given thermal image by resizing and converting the colour image into gray-scale image. In the next stage, segmentation has been performed to detect the abnormal region. From the segmented region, statistical features have been extracted for performing the classification. The obtained features were given to the classifier. The classifier classifies the data based on feature vectors. Finally, the efficiency of the classifier has been determined.

Thermal Images

Medical Thermography is used as a method of research for early pre- clinical diagnosis and control during treatment of homeostatic imbalances. Thermography is a non-invasive, non-contact tool that uses the heat from your body to aid in making diagnosis of a host of health care conditions. Thermography is completely safe and uses no radiation. DITI is a technique used for clinical applications, thermal scanning and medical research.

Fig.1.3 shows the normal thermal image of foot and fig.1.4 shows the abnormal thermal (Diabetic image) of foot.

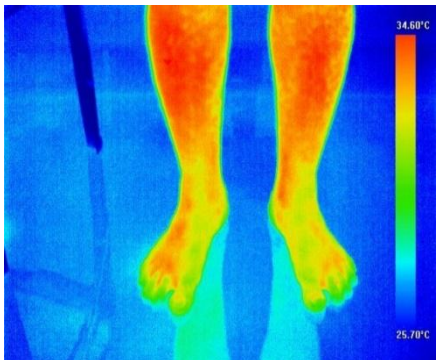


Fig.1.3

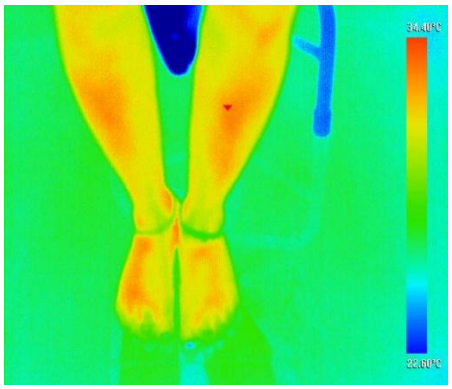
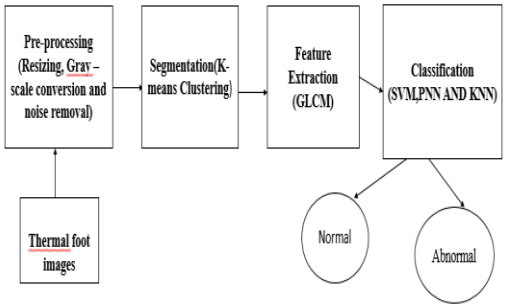


Fig.1.4

METHODOLOGY

PRE-PROCESSING

Thermal images are subjected to encompassing noise associated with a given environment, usual being a composite of a number of sources, far and near. In a thermal imaging system, the change in temperature that yields a signal-to-noise ration of unity. The aim of pre-processing is to convert the given thermal image into gray-scale image and to eliminate the above-mentioned noises.



BLOCK DIAGRAM FOR CLASSIFICATION

MEDIAN FILTER

The median filter is a non-linear method also called as sliding-window spatial filter, is used to remove noise from images while preserving edges. It is particularly effective at removing 'salt and pepper' type noise. It replaces the center value in the window with the median of all the pixel values in the window.

SEGMENTATION

After pre-processing, the dorsal and lateral surfaces of the foot have to be extracted for their temperature variations because in thermal imaging temperature variations play an important role in the detection of diabetes foot. The segmentation technique used here is the K-means clustering algorithm.

K-MEANS CLUSTERING K-Means algorithm is an unsupervised clustering algorithm that classifies the input data points into multiple classes based on their inherent distance from each other. The algorithm assumes that the data features form a vector space and tries to find natural clustering in them. The points are clustered around centroids = 1...k which are obtained by minimizing the objective ,

$$V=\sum_{i=1}^{k}\sum_{x_j\in S_i}(x_j-\mu_i)^2 \qquad (3.1)$$

where there are k clusters Si, i =1,2,….,k and μi is the centroid or mean point of all the points xj ∈ Si.

TEXTURAL FEATURES EXTRACTION

Once the segmentation is done, the textural features are extracted and analysed. We have used Gray Level Co-occurrence Matrix(GLCM) as feature extraction technique.

GRAY LEVEL CO-OCCURRENCE MATRIX The Gray Level Co-occurrence Matrix (GLCM) method is a way of extracting second order statistical texture features. The approach has been used in a number of applications, third and higher order textures consider the relationships among three or more pixels. These are theoretically possible but not commonly implemented due to calculation time and interpretation difficulty**.**

$$\textbf{CONTRAST}=\sum_{i,j}|i-j|^2\ p(i,j)$$

$$\textbf{CORRELATION}=\sum_{i,j}p(i,j)[(i-\mu_i)(j-\mu_i)/\sigma_i\sigma j]$$

$$\textbf{ENERGY}=\sum_{i,j}p(i,j)^2$$

$$\textbf{HOMOGENEITY}=\sum_{i,j}p(i,j)/(1+|i-j|)$$

$$\textbf{ENTROPY}=\text{-sum(p.*log2(p))}$$

CLASSIFIERS USED

- SUPPORT VECTOR MACHINE
- PROBABILISTIC NEURAL NETWORK
- K NEAREST NEIGHBOUR TECHNIQUE

SUPPORT VECTOR MACHINE

Support Vector Machine is a supervised machine learning method that is widely used for data analysing and pattern recognizing. It is used when the data has exactly two classes. SVM constructs a hyper plane or set of hyper planes in a high or infinite-dimensional space, which can be used for classification. An SVM classifies data by constructing the best hyper plane that separates all data points of one class from those of other class.

PROBABILISTIC NEURAL NETWORK

A probabilistic neural network (PNN) is a feedforward neural network, which is widely used in classification and pattern recognition problems. In the PNN algorithm, the parent probability distribution function (PDF) of each class is approximated by a Parzen window and a non-parametric function.

K NEAREST NEIGHBOUR

The k-nearest neighbour algorithm (k-NN) is a non-parametric method used for classification. The input consists of the k closest training sets in the feature space. In k-NN classification, the output is a class membership. An item is classifiedby a majority vote of its neighbours, with the object being assigned to the class most common among its k nearest neighbours. The nearest neighbour is determined based on the measure of Euclidean Distance.

EXPERIMENTAL RESULTS

10 normal and 25 abnormal Images were taken from 6 subjects with and without diabetes.the outputs are obtained by performing MATLAB processing.the performance and time complexity of the three classifiers are calculated. SVM classifier produces an accuracy of 75%. PNN classifier produces an accuracy of 61% and KNN produces an accuracy of 95%. Graph 5.3 shows the performance evaluation of the classifiers

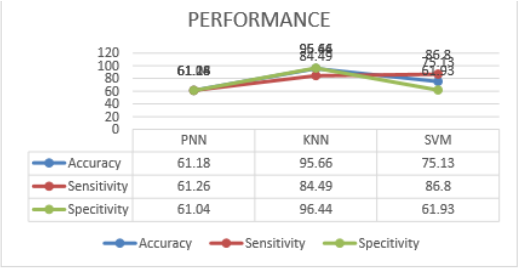


Fig 5.3 PERFORMANCE OF CLASSIFIERS

CONCLUSION AND FUTURE WORK

In this project, an automated method for the detection of foot images is implemented. Textural features are extracted from the segmented region for further analysis. SVM, PNN and KNN classifiers are used for verifying the accuracy of detection. The three classifiers are compared to find the most efficient classifier. Based on the comparison result, KNN classifier is found to be the most efficient classifier among the tested classifiers.

In future, our method would be extended to detect depth of lesions and ulcer complications of the diseases by analyzing with more number of thermal images and in real time basis images can be captured by designing low cost IR camera with good efficiency and can be subjected to further processing.

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