



## EXPERT SYSTEM FOR EARLY DETECTION OF THE FOOT ULCER IN PERIPHERAL NEUROPATHY USING THERMOGRAPHY

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### Abstract

Diabetic is a severe disease which needs an attention. In diabetes if levels of sugar in the blood rise cause damage to organs such as the nerves, heart, kidneys, and eyes. Due to this damage, the blood is provided to the skin and a nerve is reduced, causing neuropathy. Diabetic neuropathy leads to loss of sensation, numbness and sometimes pain in your feet, legs or hands which is most common complication of diabetes. Around 60% to 70% of a people with diabetes will eventually develop peripheral neuropathy. In diabetic patient the ulcer is most detecting problems. Ulcer is due to the high temperature. For early detection of ulcer Thermography is used to measure temperature and detect the abnormal area.

**Key Words:** Diabetic Neuropathy, Diabetic Foot Ulcer, Thermography, Fuzzy Expert System.

### I. Introduction

Diabetes is a disorder of metabolism. Diabetes mellitus (DM) is a major epidemic in today's world where all of the patients are at danger for developing a diabetic foot ulcer (DFU). Approximately 25% will develop some sort of the foot disease. 20% of the hospitalized cases for diabetics are due to this foot disease each year. Over foot has five main functions: 1] It is the base support for the body, 2] It can adapt to uneven ground, 3] It acts as an shock absorber for the body dung gate, 4] It provides leverage for propulsion, and 5] It absorbs transverse leg rotation. Loss of any one of these functions can be harmful to the patient, and is often noticed in a diabetic person. The second most common part of foot is heel which is affected due to the ulcer. The areas that ulcer cause, it increases temperature of that area due to inflammation and enzymatic autolysis of tissue. Five signs of inflammation are mainly characterized as redness, pain, swelling, loss of functions, and heated tissue. Temperature show our body condition, if the temperature within some area becomes lower or higher than other areas, it will be considering to have some problem such as infection, necrosis, etc. The thermal camera can be useful to measure the temperature. Thermal image is a technique that uses infrared radiation. The thermal camera is just receiving the natural thermal energy by remote temperature sensing, which is emitted by the body and no harmful energy is used in the imaging process. Thermometry is an effective way to access the risk of ulcer problems in diabetic feet's. Before other clinical signs of injury can be identified it monitors foot skin temperature and provides the clinical information.

Fuzzy rule based expert system is a good technique that can clearly capture the required medical knowledge and turn up with sound diagnosis decisions. FES uses linguistic knowledge to solve real world problems that usually require human intelligence. Expert knowledge is represented in the form of linguistic rules or as data within the computer. Linguistic rules are then used as a knowledge base for an FES to support the physicians in making decisions for medical diagnosis. Such rules can be easily verified, tuned, comprehended and possibly expanded by medical experts.

### II. Method for Data Collection

Usually our human body temperature has 37 degree Celsius and a patient who is suffering from diabetic neuropathy, their skin temperature varies according to the atmosphere's temperature. When we measure the foot's temperature using a thermal camera it does not give the appropriate output. Researchers have some conditions to avoid these problems-

1. Room temperature should be constant.
2. Subject should remove their shoes and shocks and seated or lay down, relax up to 15-20min.
3. Subject should be in ideal position.

### III. Comparatives Study

Ref. No	Methodology	Database	Method	Result
1	1. Image Analysis and Acquisition 2. Temperature Difference Percentage 3. Thermal Recovery Tendency	Own Database	1)9 patients with or without diabetes and range of age is from 18 to 80. Diagnosis of diabetes mellitus patients for approximately 10 to 20 years. 2. For static thermal image analysis, 20 images of both before and after surgery respectively. Twenty images are averaged to obtain the mean temperature.	Karhunen Loe veterans forms a better way to eliminate the area of poor circulation and early ulceration.



2	1.Mobile/camera/tab based data collection 2.Image processing algorithms 3.Patient Education	Own Database	1) Photo taken of foot from mobile camera which is less than 1mp. 2) Right and Left side of foot is detected using image processing 3) Patient education is provided.	An image processing algorithm For monitoring the insole wear patterns on the data Server for observing pressure like hotspots.
3	1.HotSpots Detection 2. Temperature Estimated Difference.	Own database	The Hospital of San Juan del Rio, Mexico, study on patients with diabetes type 2 in with the combination of a diabetes expert group. The focus group included male and female with age of 35-80.	The temperature change between corresponding regions in both feet usually does not vary beyond 1 degree Celsius, a difference greater than 2.2°C is look as abnormal.
4	1.Electromyography 2. Statistical analysis 3. Plantar thermography 4. Heartrate variability	Own Database	79 individuals between the ages of 19 and 78 years old (28males) were examine and divided into three groups: pre-diabetics (n = 13),control (n = 36) and type 2 diabetics (n =29).	Among the diabetic patients, the inter digital an isothermal technique performed better than the thermal recovery index, with a better sensitivity (81.3%) and particularity (46.2%).

**Table 1: Comparative Study**

#### IV. Medical Information

A large number of the patients register for primary detection of PMN due to complain of pain, tingling, burning and pricking sensation, weakness of limbs, problem in walking and imbalance of gait etc. The physician subject the patients for a physical examination from which he get more or less objective data and record the subjective data in electronic format for diagnosis and depending the subjective data of patient, the physician classified the disorders of patients.

#### V. Fuzzy Expert System

A Fuzzy Expert System (FES) can be considered as a special kind of expert system that is including with fuzzy sets. Thus, a FES exhibit transparency to users. Users can easily understand the decision made by an FES due to the fact that the rule base is in " IF-THEN" form used in natural languages. From a knowledge depiction view point, a fuzzy If-Then rule is a scheme to capture knowledge that is imprecise by nature.

The schematic diagram of FES structure is shown in the Fig.2. The function of the fuzzifier is to decide the degree of membership of a crisp input in a fuzzy set. The fuzzy knowledge base is used to depict the fuzzy relationship between the input and output fuzzy variables. The output of the fuzzy knowledge base is intent by the degree of membership specified by the fuzzifier. The inference engine utilizes the information from the knowledge base as well as from the fuzzifier to infer additional information. The output of a FES is a fuzzy values from the inference engine process. The function of defuzzifier is to convert the fuzzy output to the crisp values. The output in fuzzy value format is advantageous in pattern classification problems since the fuzzy values indicate the degree of belongings of a given pattern to class prototypes.

A knowledge structure used in the proposed FES is consists of the following:

- 1) Input features from thermal camera.
- 2) Variable ranges
- 3) Number of linguistic labels
- 4) Linguistic labels
- 5) Membership functions of all input/output variables
- 6) Membership function's parameters
- 7) Fuzzy if-then rules.

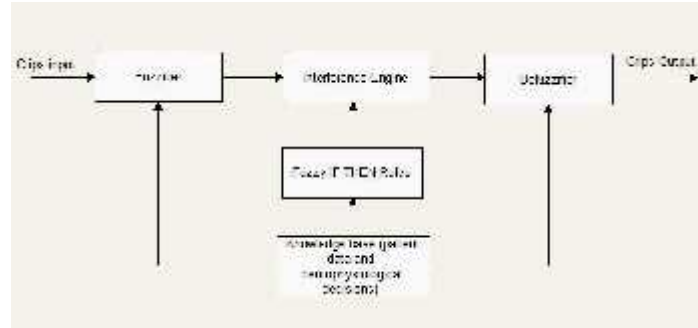


Fig.1 Fuzzy Expert System

## VI. Related Work

The Subramniam Bagavathiappan et al. have work on diabetic neuropathy. According to the research the temperature of diabetic foot is high as compare to normal feet. To proving these they compute the mean foot temperature (MFT), temperature difference ( $\Delta T$ ), and normalize temperature ( $T_N$ ). For mean foot temperature (MFT) they calculate the temperature of lesser toes temperature, arch temperature, Hallux, lateral sole temperature, heel temperature, forefoot temperature. And they use average hand temperature as a reference temperature which is use to compute the temperature difference.

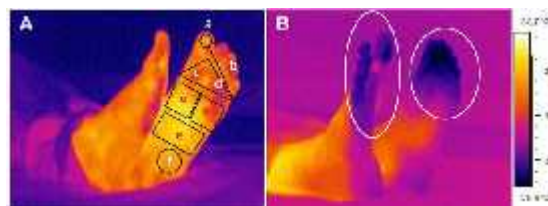
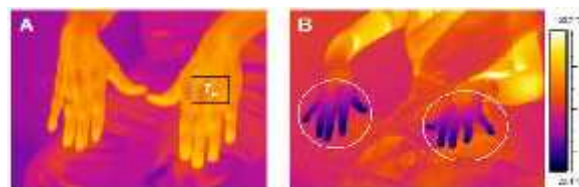


Fig. 2 (A) Thermal Image Of Feet with Hot Region and (B) Cold Region

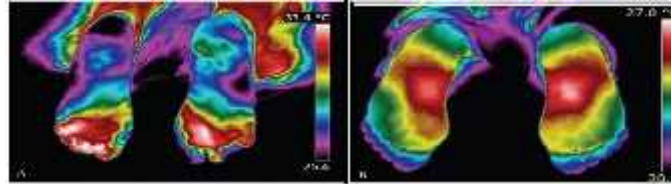
In fig(A) we can see the thermal image of feet with hotspot and six regions which is use for calculating the MFT. In fig A region a) means Hallux area, b) means lesser toes area, c) means arch area, d) means lateral sole, e) means forefoot, and f) means heel. And in fig (B) we see the cold region.



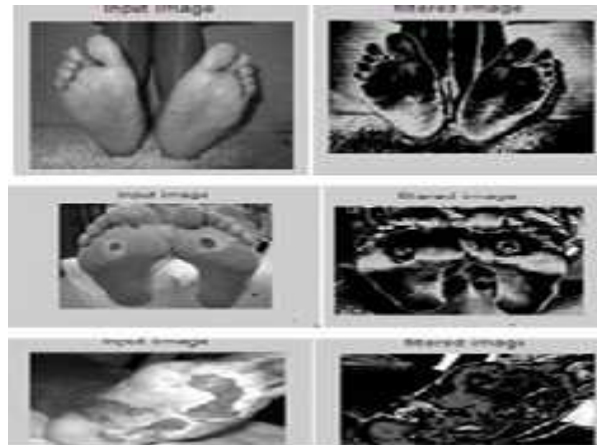
3 (A) Thermal Image of Hands of Patients and (B) Thermal Image of Patients with Coldspot in both Hands. [1]

Naima Kaabouch et al. work on diabetic feet for ulcer examination in which they use an Asymmetry Analysis technique. There is abnormal distribution of a healthy foot for the skin-surface temperature because that temperature can be affected by many factors, such as atmosphere and internal thermal conditions, as age, sex, weight, etc. for eliminate this instability they compare the temperature of both foot's and this comparison is called as symmetry or asymmetry analysis. The three steps of this technique are Segmentation, geometric transformation, and overlapping. Firstly Segmentation remove the noise as possible, Secondly Geometric transformation-adjust the same side of both foot, and last Asymmetry analysis-subtract the extremity level of each pixel in the left foot from the intensity level for the symmetric pixel of the right foot to detect rare areas. Abnormal area is detected using this technique if the intensity of this area is higher than a defined designated threshold. Using this technique they shows when the feet present as the similar shape and size in an image, it tends to detect faulty abnormal areas when the feet are not the same shape or size in the image[1].

Luciane Fachin Balbinot et al. study on Heart rate variability, plantar thermograph, Electromyography for early detection of diabetic neuropathy. According to the study in diabetic patient inter digital an isothermal test perform best when used alone. For study of plantar thermography they use a cold stress test.



**Fig.4 (A) Plantar Thermographic Image in a Diabetic Patient, Displays Inter digital an isothermal (The White Arrow Shows the Different Colors in Toes Meaning  $T \leq 0.4^{\circ}C$ ). (B) Plantar Thermographic Image of Regular in a Control Subject [1].**



**Fig.5 Foot Ulcer Image**

In my proposed system it required foot image as input. So we captured foot image by using thermal camera under a constant room temperature. From the above work we take image as input image to detect the sole in foot using fuzzy expert system. This image is compare with the knowledge based database. It contains two type of image one is a replica of foot image and other is the actual image of the foot. Firstly the input image is taken using fuzzifier than it is forwarded to the inference engine were its check with the knowledge based image whether the input image have any sole or not. In this way if the intensity of this area is higher than a specific depute threshold abnormal area is detected. That detected region goes to defuzzifier as an output. In this way the knowledge based contains various test case so afterward anyone want to refer can used directly this database. No long process to undergo.

## VII. Conclusion

In this system we make use of Fuzzy Expert System and thermal camera image to detect the foot ulcer is present or not. Using the thermal images we can detect the abnormalities of diabetic feet and expert system can detect the foot ulcer. In the future we can use more advanced technology for detecting foot ulcer and measuring body temperature.

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