GDV Based Imaging for Health Status Monitoring: Some Innovative Experiments and Developments

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ABSTRACT

New techniques using IT based Instruments are being tried everywhere to extend the reach and reliability of healthcare services. Computational bio-electro-photography based on gas discharge visualization (GDV) technique is a novel approach for monitoring health status of individuals. Increasing urbanization and the accompanying changes in lifestyles are leading to escalating epidemic of several chronic diseases including diabetes. Present research work has established that GDV imaging system can be used as an efficient tool in non-invasive diabetic screening.

Medical Imaging based systems are being deployed in various medical applications to achieve particular tasks or to find a way around some difficulties in old technologies. Various new technologies and techniques are being tried to extend the reach and reliability of health care services. Electrophotonic (or Gas Discharge Visualization) imaging is one of the ways amongst those. Diabetes is the most common disease worldwide people suffer from.

In this paper a GDV based imaging system has been reported to acquire and analyze GDV image for prognosis of diabetic patients.

Computational models and physician’s perception validate the imaging tasks and the concepts may directly be used in biomedical measurements. Followed by the development of image possessing algorithms, a computation model has been developed based on the clinical inputs from physician to validate the developed medical imaging system.

Information gain theory based machine learning algorithms are used for feature ranking. Necessary data clustering, pattern analysis and matching were done using Support Vector Machine (SVM). GDV image capturing system has been developed and used to perform planned GDV image acquisition from 85 numbers of subjects in a diabetic camp in India. The results of pilot study show tremendous possibilities towards development of a non-invasive medical aid for healthcare application like diabetes.

Keywords: Gas Discharge Visualization camera (GDV), Image Processing, Health Status Monitoring, Machine Learning, Non Invasive Diabetes Screening

1. INTRODUCTION

The principle of GDV image capturing is based on the theory of physics of gas discharge by "Kirlian" photography [1]. This technique has been used for creating contact print photographs using high voltage corona discharge between the object and the high voltage plate which is captured by the film corona discharge [2]. The design of our experiments based on the concept of capturing images by the GDV device and analysing them through innovative image processing techniques for showing difference of patterns in normal healthy subjects and unhealthy subjects (e.g. diabetes).

Computational bio-electrography based on Electrophotonic technique has been proposed as one of the tools for investigating physiological states of an individual. Several research works and experimental studies have been reported around the world on Electrophotonic technique as a medical

prognostic instrument also named as GDV (Gas Discharge Visualization) imaging camera which is available worldwide. The camera is being used as instrument by several organizations engaged in several healthcare activities using planned data collection procedure. Reviewing the papers, results, documents, books on GDV camera based system; it is found that the experiments have been done mostly on medical purposes to understand the physiological conditions of different body organs at the time of experimentations.
Based on the statistics received from the International Diabetes Federation (IDF), current estimates shows the number of diabetics in India on 2015 at about 62 million which is an increase of over 10 million from 2011 when estimates suggested that about 50.8 million people in the country were suffering from the disease. The disease has already reached endemic proportions in the country. Considering this, by the year 2030, over 100 million people in India are likely to suffer from diabetes, say researchers.
The common method of diabetes detection is conventional and invasive. In this paper an alternative way of conventional method has been experimented for non-invasive screening of diabetes using GDV (Gas Discharge Visualization) imaging camera.
A study on 85 human subjects in a diabetic camp in India was done to investigate subject's physical conditions while investigating the alternative way of conventional invasive methods of diabetes screening using GDV camera. The GDV images while fasting and 2-hour postprandial data was taken along with other blood-biochemical tests with a planned data collection procedure to record information like patient’s history, physical conditions, general habits etc in questioner session. The statistically significant GDV features were compared with the Fasting and PP glucose data and the best ranked features were extracted for classification in machine learning system.

2. OVERVIEW OF GDV TECHNIQUE

The principle of GDV camera image capture is based on the basic physics of Gas discharge by Kirlian photography technique. This technique is used for creating contact print photographs using high voltage corona discharge between the object and the high voltage plate which is captured by the film corona discharge results when the electric field is strong enough to create a chain reaction of electrons in air with by collision between atoms to ionize. The phenomena of corona discharge can be explained from the advanced theory of Townsend model. A stimulating high frequency, high voltage pulse is the cause of corona creation. Here the corona discharge from human fingers is collected as photographic image for computerized Image processing techniques and feature extraction. The discharge is basically an output of bio-physical condition of the human subject.
The basic mechanism of GDV based camera is explained in the following diagram (Fig.1) The corona discharge from human fingers is collected as photographic image for computerized processing and feature extraction (Fig.2).

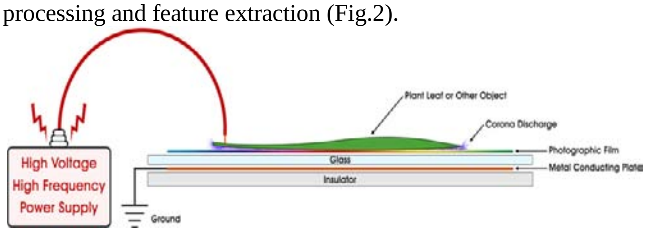

Fig1: Basic Mechanism of Gas Discharge Visualization (GDV)

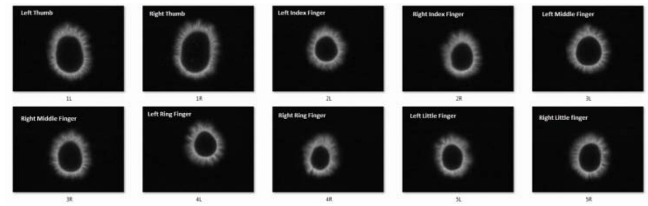

Fig2: Finger images taken in CDAC Kolkata from GDV imaging device

3. EXPERIMENTAL STUDY

An in-house experimentation was done in CDAC Kolkata center on 11 subjects to measure repeatability of the system. The data was taken twice a day for three consecutive days of same subject following the same experimental procedure for Fasting and Postprandial condition. The output obtained from statistical analysis showed encouraging results in terms of repeatability with little variation in the physical condition amongst the subjects throughout the day. The data set for system repeatability is accepted and validated by experts and doctors.

Another in-house experimentation was done at CDAC Kolkata centre in presence of GDV expert on different aspects of data collection techniques. The outcome of the session concludes that the pressure difference on the plate creates no effect on data unless there is a change in contact area of a finger on the plate. To avoid the effect of contact area, the subject is told to place the finger on the plate normally not to put extra pressure on the plate.

Based on the initial confidence gained from success of in-house experiments, a pilot study was conducted by C-DAC Kolkata at SRM Medical College & Research Centre, Chennai on 85 human subjects. The experiment was done using GDV camera to investigate the alternative way of conventional invasive method of diabetes screening. The GDV images of fasting and 2-hour postprandial condition were taken followed by other blood-biochemical tests with a planned data collection procedure to record information like patient’s history, physical conditions, general habits etc. in questionnaire form. The statistically significant GDV features were compared with the fasting and Postprandial (PP) glucose data and the best ranked features were extracted for classification using machine learning algorithm.

4. IMAGE PROCESSING AND FEATURE EXTRACTION

The novel algorithm developed and used here consists of some image processing techniques such as image segmentation, image dilation, filling image holes in particular image area, particle orientation and Centroid calculation using image subtraction technique, 8 different zone selection and overlaying for zone marking and particle zone extraction, unwrapping circular strip to rectangular strip, joining zone as particle joining, image registration for extraction of information from original greyscale image zones etc. Calculation of background versus foreground image areas for five different threshold levels was done. Finally all the ratio values for different body zones were plotted. Total 400 extracted values of each individual were used to generate statistical measure.

5. MACHINE LEARNING

The database generated from the image analysis algorithm is used for computer vision and pattern matching. The outcome is identification of some significant features extracted from the 400 features of GDV images and those are ranked to get better classification between diabetic and non-diabetic subjects. Feature ranking from the most significant image zones shows the significant classification results using different machine learning algorithms. The algorithm uses "Information Gain" theory. The algorithms are developed using Matlab statistical and Machine learning tools. Finally the system uses SVM algorithm for classification.

6. SYSTEM LAYOUT AND EXPERIMENTAL STUDY

Fig. 3 represents the steps of implementing the GDV based health status monitoring system imaging layout for the diabetic monitoring system. The GDV images were taken from diabetic subjects and controlled subjects accompanied with blood biochemical tests for Fasting and Postprandial (PP) glucose data. The GDV images are then processed for feature extraction with the help of GDV experts and machine learning. Doctor's inputs are taken for validation of diabetic and controlled level and other physical conditions of the subjects. These inputs are then used for development of machine learning and classification algorithms to converge to a prototype for health status monitoring system.
The GDV image data collection process for health status monitoring is shown in Fig 4.

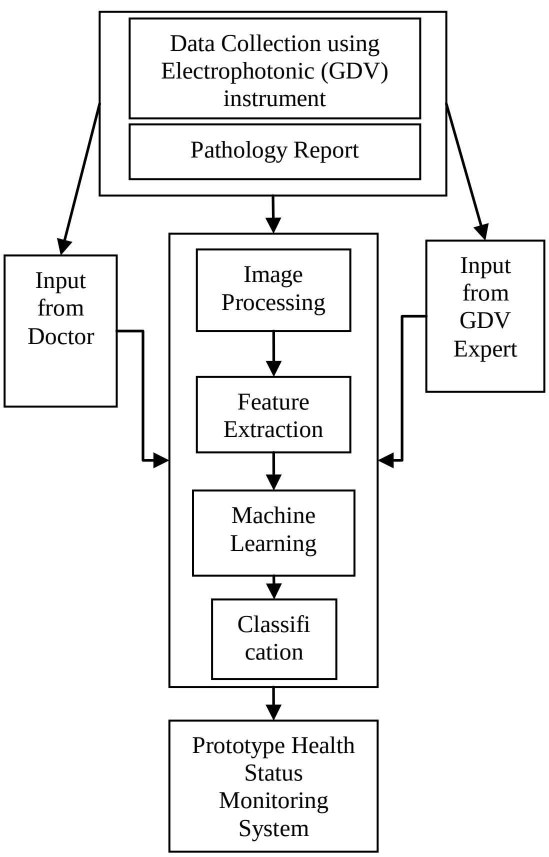

Fig3: System diagram of the health status monitoring system

Fig4: GDV data collection for health status monitoring

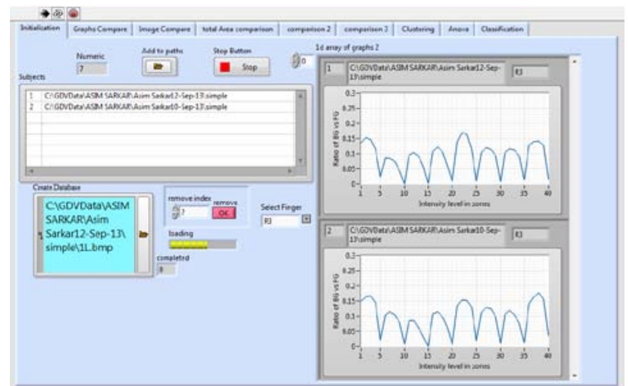

Fig5: GDV data collection and analysis software front-end

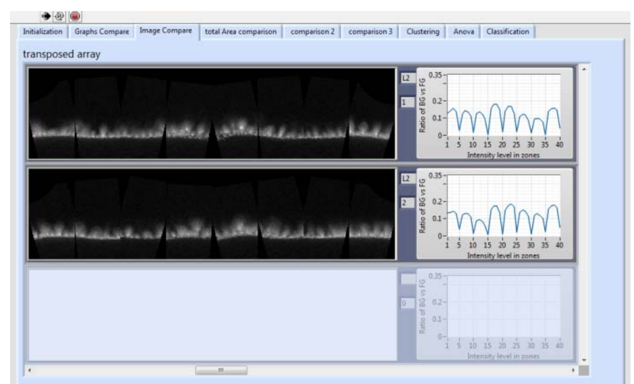

Fig6: GDV image analysis module in the developed software

Above figures (Fig 5 and Fig 6) show the glimpse of GDV image capturing and analysis software user interface developed by CDAC Kolkata team. Fig 6 represents the processed GDV images: unwrapped circular strip to rectangular strip images (at the left side of the user interface) of two subjects during the image processing and analysis steps and corresponding analysed output data (at the right side of the user interface). The plots are placed vertically to compare the differences at the zones between two subjects for a particular finger. Here 8 zones for each finger of every subject have been compared and the output data is fed to machine learning module.

7. RESULTS AND DISCUSSIONS

A study on 85 human subjects in a diabetic camp in India was done. CDAC Kolkata team conducted a collaborative GDV data collection camp with SRM Medical College Hospital and Research Centre, Chennai during September-October 2013. The

ethical clearance was obtained from the corresponding institutional ethical committee to perform the study. The informed consent form and risk assessment questionnaire was obtained from all the subjects.
Although HbA1c has been recorded for the subjects to determine type 2 diabetic or controlled subjects, our study has been focused on the temporal information as fasting and 2-hour postprandial blood sugar of the subjects to correlate with infrared images. The blood pressure (mmHg) was recorded, in the sitting position, in the right arm using sphygmomanometer. Our study group had N=85 subjects aged between 25 and 71years with male (N=36) and female (N=49). The data is obtained from all male subjects (N1=36: High=23, Control=13) and female subjects (N1=49: High=26, Control=23).

The Captured images from GDV camera are used for Image analysis. The present system of GDV based imaging consists of GDV data capture through software provided by the manufacturer and data analysis using image processing algorithm developed by CDAC Kolkata team in Labview platform.
The algorithm has been developed by taking inputs from expert suggestions and based on some references from books and other literatures. Complete algorithm consists of some basic image processing techniques namely- Image segmentation, Image Dilation, Filling Image Holes in particular image area, Particle Orientation and Centroid calculation using Image Subtraction technique, 8 different zone selection and Overlaying for Zone marking and Particle Zone extraction, Unwrap circular strip to rectangular strip, Joining Zone as particle joining, Image Registration for extraction of information from original greyscale image zones, Calculation of Background vs Foreground image areas for five different threshold levels and finally plotting all the ratio values for different body zones & send total 400 extracted values of each individual is taken in to account for statistical measure. These statistical values are treated as discriminating features for classification through machine learning algorithm. Best three significant features are ranked using information gain theory and trained for machine learning system. The algorithms are developed using Matlab statistical and Machine learning tools. The system uses SVM algorithm for machine learning.
The detailed result is discussed in Table 1 and 2 for fasting and PP respectively.

TABLE I. Population-based cross-sectional and case-control study on Fasting

	Population-based cross-sectional and case-control study on Fasting		
	Female	Male	Male + Female
Sensitivity (%)	69.23	91.30	77.42
Specificity (%)	20.00	46.15	34.78
Positive predictive value(PPV)%	77.14	75.00	76.19
Negative predictive value (NPV)%	14.28	75.00	36.36
Accuracy (%)	59.12	75.00	65.88
FNR	30.76	8.69	22.58
FPR	80	53.84	65.21
LR+	0.86	1.69	1.18
LR-	1.56	0.188	0.64
Diagnostic Odd Ratio (DOR)	0.56	9.00	1.82

Table1 shows the population-based cross-sectional and case-control study outputs for fasting.

TABLE II. Population-based cross-sectional and case-control study for PP

	Population-based cross-sectional and case-control study on PP		
	Female	Male	Male + Female
Sensitivity (%)	80.77	70.00	76.09
Specificity (%)	60.87	56.25	58.97
Positive predictive value(PPV)%	70	66.667	68.62
Negative predictive value (NPV)%	73.68	60	67.64
Accuracy (%)	71.42	63.889	68.23
FNR	19.230	30	23.91
FPR	39.130	43.75	41.02
LR+	2.0643	1.6	1.85
LR-	0.315	0.533	0.40
Diagnostic Odd Ratio (DOR)	6.533	3.0	4.57

Table 2 shows the population-based cross-sectional and case-control study outputs for postprandial data.

The overall accuracy for Fasting (M-75.00%, F-59.12%, Combined - 65.88%), positive predictivity (M-75.00%, F-77.14%, combined-76.19%), negative predictivity (M- 75.00%, F- 14.28%, Combined -36.36%), sensitivity (M-91.30%, F-69.23%, Combined-77.42%), specificity (M-46.15%, F-20.0 %, Combined - 34.78%) of the system was obtained by population-based cross-sectional and case-control study.
The overall accuracy for PP (M-63.889%, F-71.42%, Combined - 68.23%), positive predictivity (M-66.667%, F-70.0 %, combined-68.62%), negative predictivity (M- 60.00%, F-73.68%, Combined - 67.64%), sensitivity (M-70.00%, F-80.77%, Combined-76.09%), specificity (M-56.25%, F-60.87 %, Combined - 58.97%) of the system was obtained by population-based cross-sectional and case-control study.
From the results it reveals that output of the GDV system has good correlation with Fasting and PP glucose data for diabetes screening.

Although the results at this stage are qualitative because the inputs given for the training is 0 and 1 as control and diabetic cases , in future for more precise output through quantitative approach may be generated based on the acceptance of scientific bodies.

8. CONCLUSIONS

The idea of the GDV image based diabetes detection system is an outcome of Perception Engineering based application development project by CDAC Kolkata team. The features and database are gradually increasing for developmental improvement of the system. In this regard implementation of new and innovative computational method is going on to extract better performances.
This paper reflects an alternative way of conventional medical diagnostic techniques for healthcare applications using GDV imaging system as a new IT driven Instrument. The results are encouraging enough to provide a path for non-invasive diabetes screening system.

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10. REFERENCES

[1] Berney Williams, "**How Does Gas Discharge Visualization Technique Assess a Body? Emerging Models of Energy and Control in Biophysics and Physiology"**, Proceedings of the 18th IEEE Symposium on Computer-Based Medical Systems (CBMS'05).

[2] Dr. Ekaterina Yakovleva and Dr. Konstantin Korotkov, "**Electrophotonic Applications in Medicine**", ISBN 978-1481932981

[3] B. Shanmuga Priya, R. Rajesh "**Kirlian Images based Early Detection of Diabetics using Neural Network"**, 2013 IEEE

[4] Alex Vainshelboim, Michael Hayes et al **"GDV Technology Applications for Cosmetic Sciences"** Proceedings of the 18th IEEE Symposium on Computer-Based Medical Systems (CBMS'05), 2005 IEEE