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Maximal Information Compression Index (Mici) and PSO Based Detection of Jaundice

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Jaundice is one of the highest prevalent conditions demanding attention in newborn babies. Infants with high blood levels of bilirubin called hyperbilirubinaemia, evolve the yellow color when bilirubin acquires in the skin. The major symptom of jaundice is yellow coloring of the skin and conjunctiva of the eyes. Jaundice can also make babies sleepy, which can lead to poor feeding. Severe hyperbilirubinaemia can be caused by dehydration, lack of adequate nutritional intake, extravasation of blood, cephalohematoma, contusion and may be potentially cause kernicterus. Because many of these problems affect newborns, they may require critical care from specialty medical disciplines. Thus, in this paper a combination of the Maximal Information Compression Index (MICI) for redundant feature elimination with PSO optimization for complexity reduction is proposed. Statistical features are derived from the texture images and used as features to quantify infant image textures. Finally, a Kernel SVM (Support Vector Machine) is employed as a classifier for selecting infant image textures. The experimental results reveal that the proposed method can act as a supplement to support earlier detection and more effective treatment due to improved jaundice detection.

Keywords: Jaundice, Hyperbilirubinaemia, Maximal Information Compression Index (MICI), Particle Swarm Optimization (PSO), Kernel Support Vector Machine (SVM), Gray Level Co-occurrence Matrix (GLCM).

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1. INTRODUCTION

Jaundice refers to the yellow coloration of the skin, eyes and mucous membrane induced by the accretion of bilirubin in the skin and mucous membranes. Jaundice is not a disease, but is a symptom of an elevated bilirubin levels are not handled in a timely manner. Jaundice is caused by raised levels of bilirubin the body, a condition known as hyperbilirubinaemia. Most jaundice is benign, but because of the potential toxicity of bilirubin newborn infants must be monitored for early identification of severe hyperbilirubinaemia and prevention of acute bilirubin encephalopathy or kernicterus. Clinicians speculate that jaundice is a predictable clinical finding among analyst and that its pattern and intensity in newborn infants reflect the degree of elevation of the serum bilirubin concentration. Decisions regarding the need for bilirubin testing in newborns are typically based on these assumptions, but affirmatory data are limited.

Bilirubin comprises an open chain of four pyrrole-like rings (tetrapyrrole). In heme, these four rings are linked into a larger ring, termed a porphyrin ring. Bilirubin is mainly produced from the breakdown of red blood cells. Red cell breakdown produces unconjugated (or indirect) bilirubin, which circulates mostly in bound form with albumin although some is free and hence able to enter the brain. In newborns, jaundice is detected by stabilizing the skin with digital pressure so that it concedes underlying skin and subcutaneous tissue. Mild jaundice is natural in newborn baby, which normally disappears within a few days as the enzymes are formed in the body.

Texture is one of the imperative attributes used in evaluating objects or regions of interest in an image. Selection of a feature extraction approach is usually the single most crucial factor in obtaining high recognition performance in character recognition system. Feature extraction is the basis of content based image retrieval. In a broad sense, features may include text based features and visual features. Textures is an important characteristic for the analysis of many types of images, including scenes, remotely sensed data and biomedical modalities. Clinical perception and determination of jaundice can be crucial. This is especially so in babies with darker skin tones. Once jaundice is recognized, there is ambiguity about when to treat and there is a widespread deviation in the use of phototherapy and exchange transfusion.

Image texture, defined as a function of the spatial variation in pixel intensities, is useful in a variety of applications. The most commonly used approach for image texture analysis is based on the statistical properties of the intensity histogram. The Gray Level Co-occurrence Matrix (GLCM), one of the first methods used in the texture analysis, is a second order statistical approach. The classification of gray scale images has to be based on other characteristics instead of the color or multi-dimensional signature of each pixel. One effective form to classify gray scale images is to make use of the texture information presented in the image.

The texture contains significative information about the structural arrangement of objects, surfaces and their relationship with the surrounding environment. Particle Swarm Optimization (PSO) is a population based search process where individuals, referred to as particles, are grouped into a swarm. Each particle in the swarm represents a candidate solution to the optimization problem. Especially, PSO is proposed as a global optimization approach for biomedical image registration. Support vector machines (SVMs) use a linear model to implement nonlinear class boundaries through some nonlinear mapping input vectors into a high dimensional feature space.

The remaining part of the paper is organized as follows: Section II involves the works related to probable solutions for newborn infants jaundice detection. Section III involves the description of the proposed method – Newborn baby jaundice detection through the optimized feature set. Section IV involves the performance analysis of the proposed work. The paper is concluded in Section V.

2. RELATED WORK

Romagnoli, et al suggested the Italian guidelines for management and treatment of jaundice established by the task force on hyperbilirubinaemia [1]. Hyperbilirubinaemia is a very prevalent condition. The detection, prevention and management of jaundice remains a challenge specifically because of early discharge of healthy late preterm and full term newborn infants. Early discharge is accomplishing the jaundice management quite crucial, since hyperbilirubinaemia is one of the particular reasons for hospital readmission. *Prasad and Singh* [2] proposed a study on blood bilirubin levels in a tertiary care center of kumaun region. Jaundice is one of the most prevalent conditions demanding medical attention in newborn babies. Some babies are at an increased risk for developing jaundice: Babies who have Rh or ABBO incompatibility with their mothers, babies with a lot of bruising to their scalp or face during delivery, babies of diabetic mothers, premature babies, sick newborns who may not feed well in the first few days of life.

Mansor, et al suggested a k-NN algorithm and PCA based feature extraction method for early jaundice detection [3]. In infants, jaundice can be measured using invasive or non-invasive methods. However, those are only the methods to measure the level of jaundice. In babies whose bilirubin, blood levels reach hazardous levels, bilirubin may cross into the brain and cause reversible damage (called early acute bilirubin encephalopathy) or permanent damage (called kernicterus). Frequent observing and initial treatment of infants at high risk for jaundice can help to avoid severe hyperbilirubinaemia. *Nadir, et al* defined and determined the role of phototherapy in the prevention and control of neonatal jaundice [4]. Neonatal jaundice is a yellowing of the skin and other tissues of a newborn infant.

Jaundice newborns have an apparent icteric sclera and yellowing of the face, enlarging down onto the chest. In the neonate, hyperbilirubinaemia is usually due to a combination of an increased bilirubin load and decreased bilirubin elimination. *De Carvalho, et al* described the clinical approach to term and near-term (GA > 35 weeks) newborn infants with severe nonhaemolytic hyperbilirubinaemia [5]. Phototherapy is the most commonly used therapeutic option for neonatal hyperbilirubinaemia. *Azlin, et al* reported the use of Agilent 2100 bio-analyzer for the detection of the Uridine Glucuronosyl Transferase 1A1 (UDT1A1*28) [6]. A number of genetic risk factors have been implicated in the development of neonatal severe hyperbilirubinaemia.

Wells, et al [7] suggested a strategies for neonatal hyperbilirubinaemia. Hyperbilirubinaemia describes an imbalance bilirubin production, conjugation and elimination. Red blood cell and hemoglobin breakdown results in the buildup of unconjugated bilirubin, which binds to albumin and is carried to the liver. Accurate assessment is paramount to appropriate treatment of hyperbilirubinaemia. Visual assessment of jaundice may be crucial or defective, exclusively in infants with pigmented skin. *Chai, et al* proposed a paper about Gray Lev el Co-occurrence Matrix (GLCM) bone feature detection [8]. In this research, a feature detection CAD (Computer Aided Detection) based on GLCM recognition could improve the current manual inspection of x-ray imaging system. *Kaur and Sandhu* [9] suggested a human skin texture analysis using image processing techniques.

The skin texture is the appearance of the skin smooth surface. Texture refers to visual patterns or spatial arrangement of pixels that regional intensity or color alone cannot sufficiently describe. A statistical approach of exploring texture that contemplates the spatial relationship of pixels is the GLCM, also known as the gray level spatial dependence matrix. The GLCM functions describe the texture of an image by calculating how often pairs of pixels with distinct values and in an explicit spatial relationship occur in an image, forming a GLCM and then separating statistical measures from this matrix. *Shaker, et al* designed an algorithm for diagnosis of the three kinds of constitutional jaundice [10]. Constitutional jaundice is a rare disease which has little influence on either the well-being or longevity of the patient, it generally has a good prognosis. *Babu, et al* proposed a paper for the association between peak serum bilirubin and neurodevelopmental outcomes in term babies with hyperbilirubinaemia [11]. *Mondal, et al* suggested a study of Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency in neonatal jaundice [12]. G6PD is essential to maintain stability of red blood cells and G6PD deficiency was found to be a common of neonatal jaundice.

Neonatal jaundice is the most general clinical manifestation of G6PD deficiency and it has been reported that one third of children with G6PD deficiency develop neonatal jaundice. *Tuia and Gustavo* presented a semi-supervised Support Vector Machine (SVM) [13] that consolidates the information of both labeled and unlabeled pixels smoothly. This paper rec-

ommended a novel semi-supervised SVM machine based on kernels computed indirectly from clustering the image. *Sambath and Bhowmik* proposed a review of clinical features, differential diagnosis and remedies. Jaundice is not an illness, but a medical condition in which too much bilirubin a compound produced by the breakdown of hemoglobin from red blood cells in circulating in the blood [14]. The excess bilirubin causes the skin, eyes and the mucus membranes in the mouth to turn a yellowish color. Bilirubin is a yellowish pigment that is produced from the breakdown of heme, primarily from hemoglobin and red blood cells (RBCs). Bilirubin is transported by the blood to the liver, where the liver processes it, allowing it to be excreted in bile. Jaundice is common in newborn babies. It occurs as a result of the liver being underdeveloped and not fully functional.

Laddi, et al investigated a non-invasive and instant technique of jaundice detection using a machine vision approach [15]. Jaundice is a type of liver disease which is described by yellowish discoloration of the whites of the eyes, skin and mucous membranes, caused by deposition of the bile salts in these tissues. The jaundice in adults is more threatening than newborn babies and is to be treated within right time. Traditional chemical and biological methods of jaundice such as urine, serum and liver function test are time consuming and results in the severity of disease enhances to harmful level which may lead to contingency. *Bhutani, et al* proposed a paper about neonatal hyperbilirubinaemia and Rhesus disease of the newborn [16]. Neonatal hyperbilirubinaemia and jaundice occur in almost newborns.

LaFranchi suggested an approach to the diagnosis and treatment of neonatal hypothyroidism [17]. Congenital Hypothyroidism (CH) is one of the most common preventable causes of mental retardation. *Lidong, et al* proposed a paper for hyperbilirubinaemia and auditory neuropathy. The level of membrane bound hemoglobin in the blood, regarded as the symbol of oxidative stress, is higher in moderate jaundice infants compared with mild jaundice infants [18]. *Khatami, et al* proposed a paper for the inspection of the effects of blood exchange transfusion on Selenium (Se) in newborn infants [19]. This scrutiny was conducted to resolve the feasible effects of blood exchange transfusion on Se by correlating the Se blood concentrations before and after exchange transfusion in jaundiced neonates. *Bisoi, et al* [20] estimated the occurrence of G6PD deficiency among newborns and its association with disparate socio-demographic, clinical and gestational characteristics. *Halin, et al* [21] presented a soccer event detection framework for goals, penalties, yellow cards and red cards.

3. PROPOSED METHOD

The goal of this paper is to promote a new method of newborn jaundice monitoring based on a combination of a PSO optimization with maximal index

compression index to detect jaundice in infants that can act as a supplemental support for earlier and more effective jaundice recognition. The development of a jaundice detection system involves the following tasks:

- Skin Detection
- Preprocessing
- Feature Extraction
- Feature Selection
- Kernel SVM Prediction

3.1 Skin Detection

Skin detection can be defined as the process of selecting which pixels of a given image correspond to human skin. Skin detection is useful in face detection and face tracking. Skin color is affected by ambient light which is unknown in many situations; disparate cameras produce different colors, even from the same person, under the same illumination conditions and finally, skin colors change from person to person. YCbCr has been widely used for the skin pixels form a compact cluster in the Cb-Cr plane. Skin color is distinct, and since color is a low level attribute of the image, any operation done with color will be fast. Measurement of skin reflectance, light spectral power distribution and camera channel sensitivities allow the computation of ideal RGB values for different skin types. Conversion to normalized color space *(r, g)* chromaticity diminishes brightness dependence. Where,

$$r = R / (R + G + B) \tag{1}$$

$$g = G / (R + G + B) \tag{2}$$

Actual measurements have shown that dark, yellowish and pale skin have almost the same chromaticity.

3.2 Preprocessing

In this analysis, a novel filter structure is used namely, Hybrid Median Filter, which constitutes a natural extension of the nonlinear rational type hybrid filters. A method for processing an image, consisting of a foreground and a background to produce a highly compressed and accurate representation of the image. In hybrid median filtering, the neighboring pixels are ranked according to brightness (intensity) and the median value becomes the new value for the central pixels. In the median filtering operation, the pixel values in the neighborhood window are ranked according to intensity and the middle value (median) becomes the output value for the pixel under evaluation. The hybrid median filter is more expensive to compute than a smoothing filter.

Given a set of random variables M = (M_1, M_2, … M_N), the order statistics $M_{(1)} \leq M_{(2)} \leq \ldots M_{(N)}$ are random variables, defined by sorting the values of M_i in an increasing order. The median value is then given as,

$$\text{Median (M)} = \begin{Bmatrix} M_{(A+1)} = M_{(f)}, & for\ X = 2A+1 \\ \frac{1}{2}(M_{(A)} + M_{(A+1)}, & for\ X = 2A \end{Bmatrix} \tag{3}$$

Where, f = 2A + 1 is the median rank. The median is considered to be a robust estimator of the location parameter of a distribution and has found numerous applications in smoothing. For a grayscale input image with intensity values $x_{i,j}$, the hybrid median filter is defined as,

$$Y_{i,j} = \underset{(a,b) \in G}{median}(X_{i+r,j+s}) \tag{4}$$

Where, G is a window over which the filter is applied. The symmetric square window of size A X A with A = 2C + 1, i.e., the median rank f equals f = $(A^2 + 1)/2$. This is probably also the most widely used form of this filter.

3.3 Feature Extraction

The extraction of image features is the fundamental step for image classification. There are various types of features for image classification's aim as follows: color, statistical features, shape features and transform coefficient features. Feature extraction is a method of capturing the visual content of images for indexing and retrieval. Texture is one of the imperative characteristics used in identifying objects or regions of interest in an image. Selection of a feature extraction approach is usually the single most crucial factor in accomplishing high recognition performance in character recognition systems. A common technique in texture analysis involves the computation of GLCM as a second order texture measure. Color is one of the most widely use visual features and is variant to image size and orientation. GLCM method is based on extraction of grayscale images, this approach is to improve these techniques to color extraction. For extraction of color texture features, RGB and HSV color spaces are used. HSV (Hue, Saturation and Value) color space is a nonlinear transformation of the RGB color space. Feature vector is computed for every Hue (H), Saturation (S) and Value (V) channel:

$$\begin{aligned} \text{FV} = [&\text{mean (H), mean (S), mean (V), variance (H),} \\ &\text{variance (S), variance (V), skewness (H),} \\ &\text{skewness (S), skewness (V)}] \end{aligned} \tag{5}$$

Where, FV – Feature Vector. GLCM describes the frequency of one gray tone appearing in a specified spatial linear relationship with another gray tone, within the area under investigation. Several statistical parameters can be extracted from the GLCM. Some of these parameters are related to specific first order statistical approaches, such as variance and contrast and have a clear textural meaning. The GLCM functions are used to indicate the texture of an image by considering how often pairs of pixel with distinct values and in a stated spatial relationship that occurs in an image. This created GLCM is then used for extracting statistical measures. GLCM is a second order statistical feature which contains information about pixels having similar gray level values in an image. Feature extraction associates facilitating the amount of resources required to define a large set of data precisely. Feature extraction is a regular term for approaches of formulating aggregations of the variables to get around these obstacles while still characterizing the data with competent accuracy.

3.4 Feature Selection

In this investigation, a new measure is proposed, called the Maximal Information Compression Index (MICI) to be used for feature selection. There are typically two possible approaches for measuring similarity between two random variables.

Let $\sum$ be the covariance matrix of random variables a_1 and a_2. Define, Maximal Information Compression Index (MICI) as (a_1, a_2) = smallest eigenvalue of $\sum$, i.e.,

$$2\delta(a_{1,}\, a_2) = (\text{var}(a_1) + \text{var}(a_2) - \sqrt{\text{var}(a_1 + \text{var}(a_2))^2 - 4\,\text{var}(a_1)\,\text{var}(a_2)(1 - \text{P}(a_1 + a_2)^2} \tag{6}$$

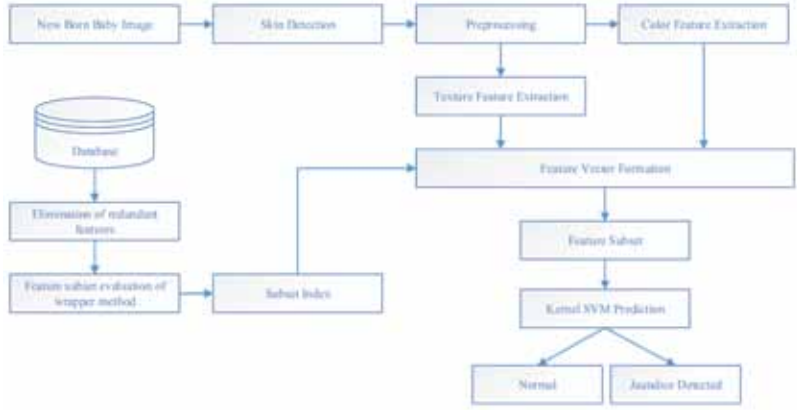

FIGURE 1
Newborn baby jaundice detection through an optimized feature set.

The value of δ is zero when the features are linearly defenseless and enhances as amount of dependency decreases. It may be noted that the measure δ is nothing but the eigenvalue for the direction normal of feature pair (a_1+a_2). The maximum information compression is achieved if a multivariate data is projected along its principal component direction. The corresponding loss of information in reconstruction of the pattern is equal to the eigenvalue along the direction normal to the principal component. Hence, δ is the amount of reconstruction error committed if the data is projected to a diminished dimension in the best possible way. Therefore, it is a measure of the minimum amount of information loss or the maximum amount of information compression possible.

One is for non-parametrically test the closeness of probability distributions of the variables. There are several benefits of choosing linear dependency as a feature similarity measure. It is known that if some of the features are linearly dependent on the others and if the data is linearly separable in the original representation, the data is still linearly separable if all but one of the linearly dependent features are removed. The task of feature selection includes two steps, namely, partitioning the original feature set into a number of homogeneous subsets and selecting a representative feature from each subset. In this work, a measure of linear dependency is suggested for feature selection. Conventional methods of feature selection involve evaluating various feature subsets using some index and selecting the best among them. A problem of these methods, when applied to large datasets, is the high computational complexity involved in searching. PSO is used for reducing the high complexity during feature selection.

Particle Swarm Optimization (PSO) is proposed as a global optimization approach for biomedical image registration. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. The objective of the proposed PSO is to maximize an objective fitness criterion in order to diminish the high complexity. PSO is one of the modern heuristic algorithms that can be applied to non-linear and non-continuous optimization problems. It is a population based stochastic optimization technique for continuous non-linear functions. The algorithm then searches for optima through a series of iterations. The particle's fitness values is evaluated for each iteration. The algorithm of PSO is used to find the best values of thresholds that can give an appropriate partition for a target image according to a fitness function.

3.5 Kernel SVM Prediction

The Support Vector Machine is a theoretically superior machine learning methodology with great results in pattern recognition. The function can be a classification function or the function can be a general regression function. The kernel based method is based on mapping data from the initial input feature space to a kernel feature space of higher dimensionality and then determining a non-linear problem in that space. These techniques allow us to

interpret learning algorithms geometrically in the kernel space, thus incorporating statistics and geometry in an efficient way.

4. PERFORMANCE ANALYSIS

The experimental results are used to detect the jaundice in newborn babies. Jaundice is due to a buildup in the blood of bilirubin, a yellow pigment which comes from the breakdown of old red blood cells. It is normal for red blood cells to break-down, but the bilirubin formed does not generally cause jaundice because the liver metabolizes it and gets rid of it into the gut. Newborn babies are often affected by jaundice, which makes their skin and eyes have a yellowish tinge. Other symptoms may incorporate drowsing, feeding troubles and dark urine. Bilirubin is a waste product of the body's breakdown of old and damaged red blood cells.

4.1 Preprocessing

Fig 2. (A) depicts the input image. Baby image 16 is given as the input image. The newborn danger signs are defined as the signs which occur in the newborn within 30days of life such as pathological jaundice, poor feeding and excessive weight loss.

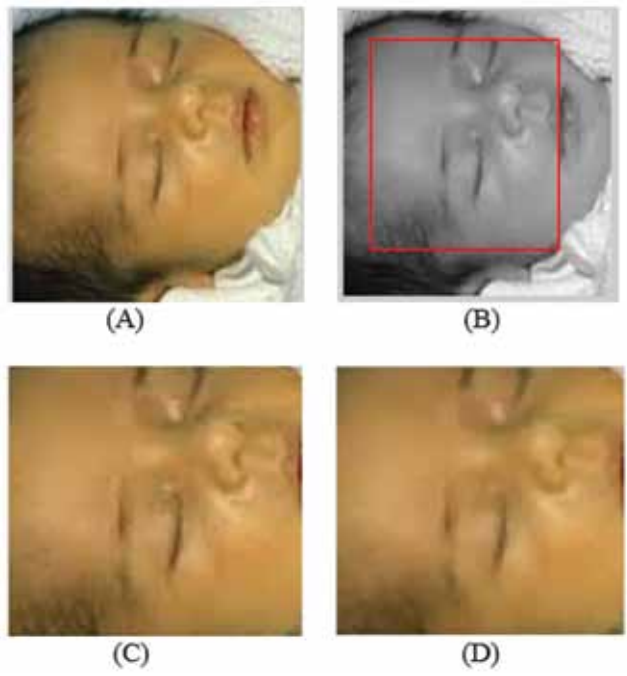

FIGURE 2
Skin Detection and preprocessing.

Fig 2. (B) shows the skin detection. The preeminent demand in skin detection is to constitute the recognition robust to the large variations in appearance of skin that may occur, like shape, intensity, color, etc. Skin color and texture are important cues that people use consciously or unconsciously to infer variety of culture related aspects about each other. Skin detection is the process of finding skin colored pixels and regions in an input image.

Fig 2. (C) represents the region of interest. A region of interest is a portion of an image that performs the filter operation on the image. Fig 2. (D) illustrates the preprocessed image. In this work, the hybrid median filtering technique is used for preprocessing. The aim of preprocessing is an improvement of the image data that suppresses unwanted distortions or enhances some image features important for further processing.

4.2 Mean fitness value calculation

Fig 3. depicts the mean fitness value calculation. In this graph, the x-axis represents the iterations and the y-axis represents the fitness value. The average fitness of the whole population is the fitness of each genotype multiplied by its frequency, this is known as mean fitness.

4.3 Best fitness value calculation

Fig 4. Depicts the best fitness value calculation. In this graph, the x-axis represents the iterations and the y-axis represents the fitness values for each iteration.

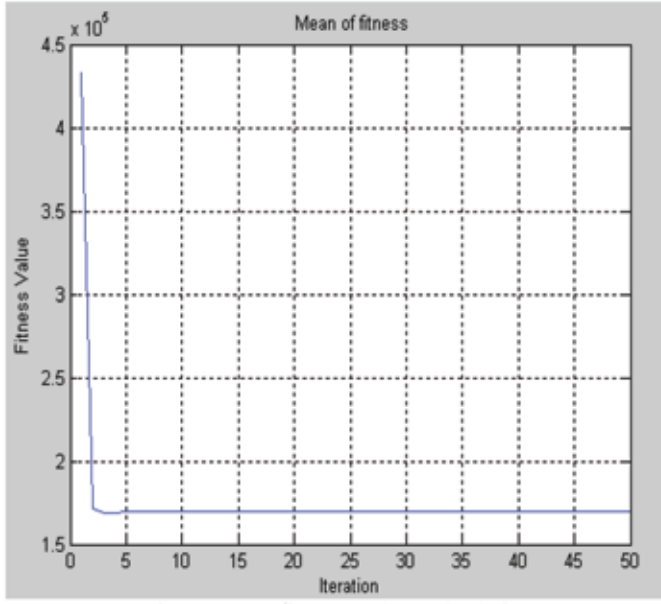

FIGURE 3
Mean fitness value calculation.

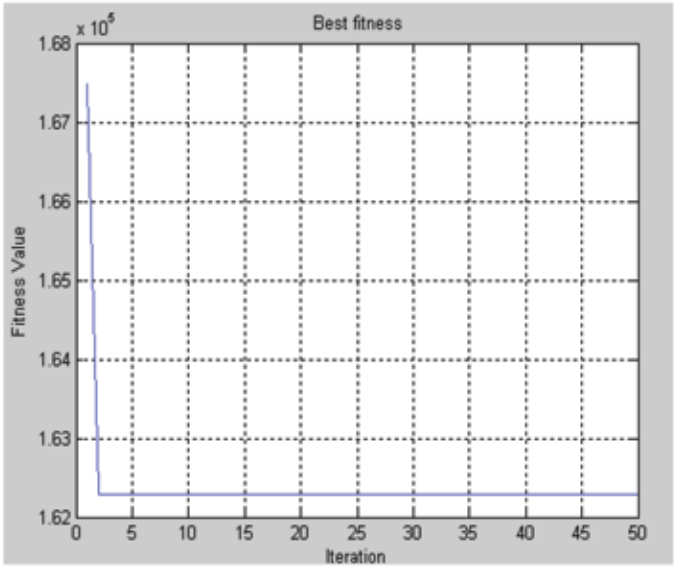

FIGURE 4
Best fitness value calculation.

4.4 Confusion Matrix

Fig 5. Shows the confusion matrix. The confusion matrix function allows comparison of a classified image. A confusion matrix contains information about actual and predicted classifications done by a classification system. Performance of such systems is commonly evaluated using the data in the matrix. Each column of the confusion matrix exemplifies a ground truth class and the values in the column coincide with the classification image's labeling of the ground truth pixels.

4.5 Overall Analysis

The comparison between the normal babies and jaundice affected babies are shown in Fig 6. In this analysis, the level of jaundice prediction rate and the accuracy rate are increased by using the combination of maximal information compression index with PSO. Kernel SVM classifier is used to classify the normal babies and the jaundice detected babies.

5. CONCLUSION AND FUTURE WORK

Jaundice is one of the most familiar conditions demanding medical attention in newborn babies. Jaundice refers to yellow coloration of the skin and the sclerae and is induced by a constructed level of bilirubin in the circulation, a position recognized as hyperbilirubinaemia. In this research, preprocessing is

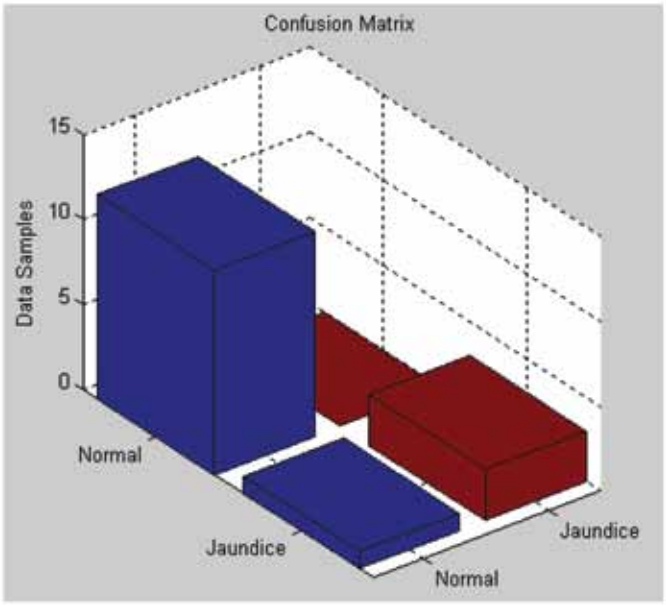

FIGURE 5
Confusion matrix.

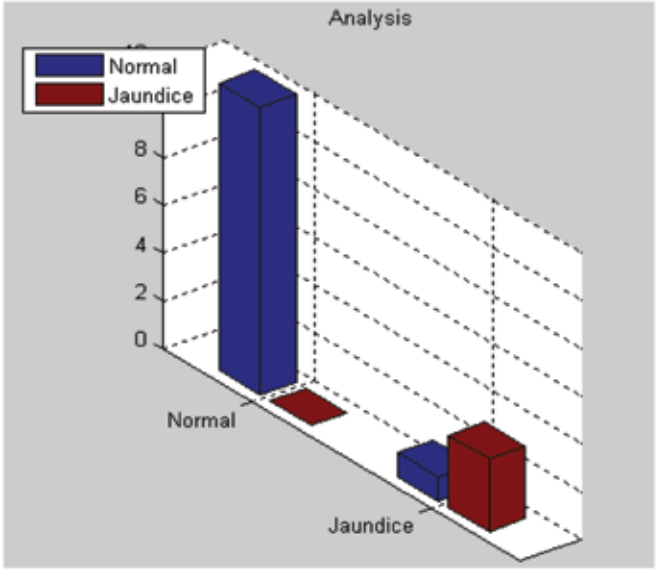

FIGURE 6
Overall Analysis.

done by using the hybrid median filtering technique and GLCM is used for texture feature extraction and color feature extraction. After extracting the features, the redundant features are eliminated by using the proposed Maximal Information Compression Index (MICI). Hence, the Particle Swarm Optimization (PSO) algorithm is used to reduce the complexity. Finally, the Kernel Support Vector Machine (SVM) is used to classify the normal babies and jaundice detected babies.

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