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Diagnosis of Osteoarthritis (OA) Progression using Image Processing

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***Abstract*: Knee Osteoarthritis is a kind of joint inflammation, which often occurs in one or both the knee joints. Osteoarthritis is often called as 'wear and tear' process of joint that results in dynamic disintegration of articular cartilage. Cartilage is smooth substantial layer that ensures movement to occur effortlessly. In Osteoarthritis, cartilage is inclined towards the destruction as it loses elasticity and becomes brittle. Our project deals with the detection of Osteoarthritis (OA) progression of any age group of people. According to the centers for Disease Control and Prevention (CDC), OA affects 27 million people. We have proposed a new algorithm to detect OA using machine learning techniques in image processing, which is more accurate for finding the severity of the knee OA than the existing methods in which the accuracy level was not sufficient enough for OA analysis.**

***Keywords*: Osteoarthritis, X-ray, Kellgren Lawrence (KL) Classification, SVM algorithm.**

1. Introduction

Osteoarthritis is one of the most common form of arthritis disease that is seen mostly in females, overweight and elderly people. Osteoarthritis (OA) is the joint disease that mostly affects the cartilage. Cartilage is the connective tissue that covers the end of bones in a joint. The normal or healthy cartilage allows easy glide of bone in the joint and prevent them from rubbing each other. In Osteoarthritis the top layer of cartilage is erupted due to which the bones rub each other causing severe pain. The Osteoarthritis commonly affects the joints in the knee, hip, spine and feet. There are two types of Osteoarthritis, Primary OA seen in aged people due to their genetic reasons or aging. Secondary OA tends to show up earlier in life due to some injury, obesity, athletics or patients with rheumatoid arthritis. The main symptoms of OA are pain and difficulty in joint motion, reduced function and participation restriction and Joint stiffness in the morning or after prolonged rest.

Currently diagnosis of Osteoarthritis is based upon patient-reported symptoms and X-rays. The alternative solution is MRI with high cost and it is rarely used until symptoms progress and patients are referred for specialist surgical opinion. Despite the introduction of several imaging techniques such as MRI, Optical Coherence Tomography and ultrasound for augmented OA diagnosis, the radiography (X-ray) has been traditionally preferred. It remains the main accessible tool and 'gold standard' for knee OA diagnosis. The common X-ray findings of Osteoarthritis include destruction of joint cartilage; joint space is diminished between adjoining bones and bone spur formation.

Fig. 1. Normal Knee Image

Fig. 2. Osteoarthritis Knee Image

The objective of this project is to design a new algorithm to detect OA using machine learning techniques which is more accurate for finding the severity of the knee OA than the existing methods in which the accuracy level was not sufficient enough for OA analysis. [2] OA analysis involves following steps: first, collection of X-ray knee images of different people. Secondly, design a filter, then extract feature vector as dataset, and classify each dataset based on different KL- grade. To overcome nonlinearity problems by analysis of osteoarthritis using linear regression in Support vector machine (SVM). Hence, samples will be used for testing which represent normal and high severity levels of OA.

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2. Proposed methodology

The proposed methodology consists of four main steps, Preprocessing, Feature extraction using Euclidean distance and Classification of computed features. The steps are explained in the following subsections.

A. Image Acquisition

Image acquisition can be designated as the action of fetching an image from some source which is further processed to get new and better image.

Data Set: We have used the input data set of 125 knees X-ray images that were collected from various hospitals and diagnostic centre. The images collected were based on various specifications like age, gender, occupation etc.

B. Pre-processing

Pre-processing highlights some important features relevant to the X-ray image. After collection of knee X-ray images, initially pre-processing techniques are used which are application dependent. In the work pre-processing is carried out by cropping the image to 515x408 pixels and resized to 200x200 for the proper analysis.

C. Image Enhancement

Enhancement techniques are used to improve the quality of the image to great extent. In the work segmented knee X ray images are enhanced by contrast adjustment to get better extremity of an image.

D. Feature extraction using Euclidean distance

Feature Matching is represented by the inner product which is mathematically simple procedure. Feature matching can be extended naturally in terms of its mathematical structure to the subspace method.

Finding position right knee and left knee in a given knee X-ray image is performed by first downscaling the 2828×2320 image by a factor 40, i.e.,

$$x' = round\ (x/m)$$
$$y' = round\ (y/m)$$

Were m=40 is scale factor, x' is scaled, width is y' is scaled height, x is width of the image and y is height of the image [8].

For right knee the scanning proceeds from the x'=1 to x'=18 and y'=1 to y'=20 and left knee the scanning goes from the x'=47 to x'=64 and y'=1 to y'=20. Each position the Euclidean distances between the 40×57 pixels are computed as,

$$d_{i,w} = \sqrt{\sum\sum(I_{x',y'} - W_{x,y})^2}$$

Where $W_{x,y}$ is the intensity of pixel x, y in the shifted window W, $I_{x',y'}$ is the intensity of the pixel x', y' in the image I, and $d_{i,w}$ is the Euclidean distance between the joint image *I* and the 40×57 shifted window *W*.

This simple and fast method was able to successfully find the position of the right knee and the left knee in all images in the dataset. Then we multiply the position with the scale factor as follows:

$$x = round\ (x'*m)$$
$$y = round\ (y'*m)$$

After finding the rescaled feature position, we determine its center of mass coordinates:

$xc = M1,0/M0,0$ and $yc = M0,1/M0,0$ with

$$M_{i,j} = \iint x^i y^j \, dxdy$$

where $M_{i,j}$ is moment of order *i,j*.

Row sum graph

Once the knees have been located, we use row sum graphs to determine the junction area. The sum graph represents the row-wise summation of gray values.

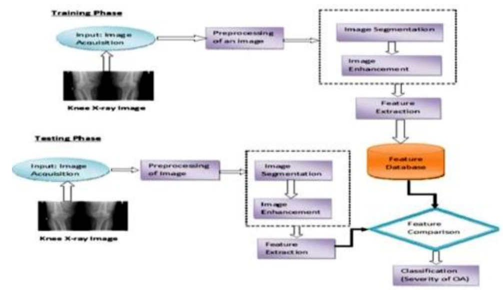

Fig. 1. Training and testing phase

E. Classification

With the extracted features from the above explained method, a dataset has been created for further classification. The support Vector Machine (SVM) is used to classify the database of knee joint X-ray Images. SVM is superior to all other machines learning algorithm. With the help of extracted features Support Vector Machine (SVM) is trained which expresses the severity level of osteoarthritis. [5] SVM works in two phases i.e. Training and testing. SVM is trained with the feature matrix and class label. The decision model is implemented which assign the class to the input data base.

3. KL grade analysis

Kellgren-Lawrence Grading System is the most validate method for classifying the knee OA severity of individuals. The scale of the KL grading system is divided into four grades.

Grade 1: Indicate there is no knee OA or doubtful narrowing of joint space and possible osteophyte lipping

Grade 2: presence of osteophytes and narrowing of joint space

Grade 3: presence of moderate multiple osteophytes and definite narrowing of joints space, some sclerosis and possible deformity of bone contour

Grade 4: presence of large osteophytes marked narrowing of joint space, severe sclerosis definite deformity of bone contour.

This classification is based on features of osteophytes (bony growths adjacent to the joint space), narrowing of part or all of the tibial–femoral joint space, and sclerosis of the subchondral bone.

4. Conclusion

In this paper we described an automated method for the diagnosis of OA severity levels using knee X-rays. This method is a data driven approach which is used on different data set to diagnosis the osteoarthritis. Experimental results suggest that more than 65% of OA cases are diagnosed. Our future work will include development of regression models for prediction of OA in knee and hand joints and evaluation of the models developed in longitudinal and prospective studies.

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