Medical Image Analysis for Bone Fracture Detection

Theoretical Proposal using Machine Learning

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***Abstract*— Static image analysis is an important concept in computer vision. In medical Image processing identifying bone fractures from the given image is an important task. The proposed method is used find bone fractures in human beings. The technique is robust enough to detect both major and hairline fractures. This is achieved by combining Canny Edge Detector and the Hough Transform method. A theoretical proposal includes using machine learning to make the software intelligent. Presently in the literature people use stochastic grammar for representation where probability for each production rule is defined which in turn will set a weight-age for selection by using Bayesian likelihood estimation. For learning purpose we can use unsupervised learning, which makes use of algorithms that draw inferences from data-sets consisting of input data without labelled responses. The proposed paper aims to perform image analysis in order to parse a larger number of images of varying complexities as efficiently as possible, where efficiency pertains to speed of analysing the image and accuracy of analysing the image. Digital image analysis performs image analysis in a static fashion, i.e. it has a fixed rate of analysing the image irrespective of how many ever times you analyse the same image or another image, there is no way to improve the scheme. In contrast, unsupervised learning starts the analysis at a slow rate, but with passage of images its efficiency improves as it learns how to analyse better. Added to this is the added advantage of intelligence, hence as earlier mentioned the system learns ensuring no human interference.**

***Key words:* Stochastic Grammar, And-Or Graph, Bayesian Estimation, Canny-Edge Detector, Hough Transform, Gaussian filter**

1. INTRODUCTION

The main purpose of the paper is to present an idea by which a machine may perform automatic image analysis hence being able to diagnose particular problems in the particular organ in question. For the scope of the project, the chosen organ is a bone and fracture has been selected as the criterion. To this we also make a theoretical proposal to extend the usability of the project. The present status includes making use of computer vision and digital image processing in order to process an image and accordingly recognize the area of fracture in the bone and demarcate it. The algorithm is robust enough to detect major and minor fractures while not confusing fractures and bone joints. The theoretical approach includes making use of machine learning in order to recognize the organ in question, classify as fit and unfit and further make use of stochastic grammar in order to give the patient disease diagnosis depending on the ailment being suffered in the particular organ.

2. RELATED CONCEPTS

2.1 Image Processing

An image can be represented in the form of a two dimensional function in the form of f(x, y) where x and y are the spatial co-ordinates and the amplitude of 'f' at any pair of co-ordinates (x, y) is called as the intensity or gray level of the image at that particular point of the image in question. When the values of x, y and the intensity values of 'f' are all finite and discrete quantities, the image is called as a digital image. Image Processing refers to the processing of these images in order to be understood easily by computers which in turn run on digital logic. The most common images that are made use of for the purpose of image processing are X-Ray images and Infrared images. [7]

2.2 Computer Vision

Computer Vision (CV) is a field under Computer Science that consists of methodologies to understand an image that has been fed to the system. It includes the ability to understand high dimensional image and convert it to numerical data. This symbolic data can be used in the field of statistics, physics and learning theory in order to teach the computer to understand the image fed to the system. The system proposed by us involves taking high dimensional input image data (in our case bone images) in order to enter it into the system. The main aim of the project is teaching the system to recognize major flaws in the bone, in our case major fractures and stress fractures. There are many applications of computer vision and can be extrapolated into many fields such as digital image processing, artificial intelligence, statistics, physics, etc.

2.3 Pattern Recognition

Pattern recognition is a field under Artificial intelligence, more precisely speaking under machine learning that focuses on recognising patterns and regularities/irregularities in data, although it is considered to be as good as machine learning in certain situations. Pattern recognition in most cases makes use of sample training and testing data, i.e. data that is already labelled. This form of learning is called as supervised learning. If there is no labelled data available and the machine is trained to recognise previously unrecognisable patterns it is called as unsupervised learning.

2.4 Machine Learning

Machine Learning (ML) is a field of Computer Science that falls under the heading of Artificial Intelligence. It gives the computer the ability to learn without explicitly programming it. The study of ML is closely involved and overlapped with

the study of statistics, to be more precise computational statistics which makes use of strong mathematical prediction models. ML is used in a number of areas [5]; applications include spam mail filtering, search engine usage, data mining (which essentially makes use of unsupervised learning) and many more.

2.5 And-Or Graph

We have a pleasing trend in the syntactic pattern recognition where images are represented by making use of stochastic grammars. Here, each production rule is attached with a probability 'P_i' (the sum of the probabilities of all the rules put together should be 1). According to the And-Or graph method presented by Zhu and Mumford [9], the image is represented by making use of Stochastic Context Free Grammar (SCFG), where the root node represents the given image, subsequently the non-terminal nodes represent sub-components of the image and the terminals represent the primitives. In And-Or graph representation, 'Or' node represents alternative sub-configuration and 'And' node represents dividing a component into its sub-components. It uses spatial and functional relations by using horizontal links between nodes.

2.5.1 Image Parsing

According to Zhu and Mumford [9], Image parsing is the task of finding the most suitable parse graph of the given input image, which is a subgraph of And-Or graph. They used Bayesian likelihood estimation to conclude the image parsing.
[9]

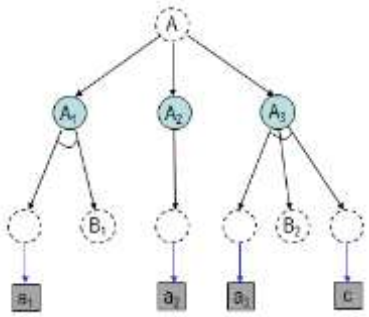


Fig-1

The And-Or graph for the grammar
A → aB | a | aBc is shown above in fig 1 ,In this dotted circle represents Or node and solid circles represent And nodes.

3 VARIOUS TECHNIQUES

Various techniques made use of in digital image processing are:

- Pixilation
- Linear filtering
- Image editing
- Image restoration
- Component analysis
- Markov models
- Neural Networks

There are many methodologies that can be made use of for image processing out of which few are as follows [4]:

3.1 Enhancement

Image Enhancement is the process of adjusting or improving the quality of a digital image so that the final result may be used for the purpose of image analysis. [3] Certain examples of how image enhancement may be done are noise reduction, sharpening and brightening.

3.2 Convolution

Convolution is a general purpose filter effect for the purpose of improving image quality. It may be considered as a matrix applied to an image and a mathematical operator which is comprised of a number of integers. [8]
It works by determining the value of a central pixel and adding the weighted values of the neighbours all together. The final output will be a newly modified filtered image.

3.3 Noise Filters

Noise filters are used for the purpose of diminishing noise, i.e. statistical deviations from an input signal which in our case is an image. [4]

The various noise filters made use of are:

- Sigma filter
- Median-filter
- Adaptive-smoothing filter

3.4 Edge Detection

Edge detection is an image processing technique used for the purpose of finding boundaries in images. [3] This is achieved by recognizing the dark and bright regions in the image. Edge detection is mainly used for the purpose of image segmentation and feature extraction used mainly in computer vision, machine learning and image processing.

3.4.1 Image Segmentation

Image Segmentation is the process of dicing and dividing an image into several parts. This is a method used a lot in feature extraction for the purpose of machine learning.

3.4.2 Feature Extraction

Related to dimensionality reduction, feature extraction involves building derived values from initial raw data to build an informative and non-redundant output. It is used in machine learning and image processing in order to extract the required and useful features from a given image.

3.5 Canny Edge Detector

This is an edge detection system that makes use of a multi stage algorithm in order to detect a range of edges [1]. It can be used as a feature extraction technique in order to obtain structural information from objects. The main objective of the edge detector is to detect edges, in the form of deformations in the image. With respect to the project, the main obstacle to overcome was to make sure the edge detector didn't confuse between a joint and a fracture as both fall under the category of edges.

The 5 simple steps into which Canny Edge detection may be broken down into are [6]:

1. Apply Gaussian filter on a smooth image surface in order to remove surrounding noise from the image.

2. Find the intensity points and gradients on the image.
3. Apply non-maximum suppression, i.e. edge thinning to get rid of redundant responses.
4. Apply double threshold in order to detect the potential edges of the image.
5. Finalize the edge detection by suppressing the unnecessary edges.

Gaussian fiter is used in order to remove the noise that may potentially affect the performance of the image analysis. Hence the Gaussian filter helps convolve the smooth image.

3.6 Hough Transform

The Hough transform is a technique which can be used to isolate features of a particular shape within an image.[homepages] Because it requires that the desired features be specified in some parametric form, the *classical* Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, *etc.* A *generalized* Hough transform can be employed in applications where a simple analytic description of a feature(s) is not possible. Due to the computational complexity of the generalized Hough algorithm, we restrict the main focus of this discussion to the classical Hough transform. The Hough technique is particularly useful for computing a global description of a feature(s) (where the number of solution classes need not be known *a priori*), given (possibly noisy) local measurements. The motivating idea behind the Hough technique for line detection is that each input measurement (*e.g.* coordinate point) indicates its contribution to a globally consistent solution.

4 IMPROVEMENT OVER EXISTING TECHNIQUE

There are many systems made for the purpose of image recognition and pattern recognition in today's technological market because of the growing demand of their need. Pattern recognition is used in a variety of field, one of the most pressing and important need of today's market being signature verification. This is done in order to verify for forgery in order to protect the privacy of the clients. In a similar fashion, image recognition is another field that is widely being made use of and further increasing in importance due its varied applications and number of software programs that support it. A very common use of image recognition can be seen in autonomous systems and more importantly in many upcoming self-surveillance cameras in order to recognise who is passing the camera at what time.

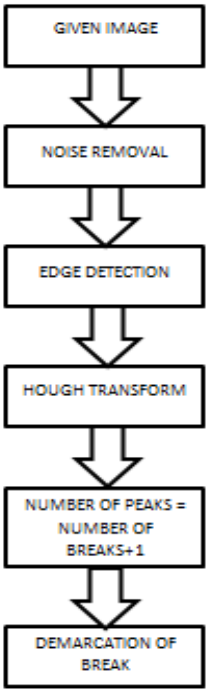
Another field that is slowly but steadily gaining a grip on today's fast growing market is Artificial Intelligence. AI is the intelligence exhibited by machines or software. It is also the name of the academic field of study which studies how to create computers and computer software that are capable of intelligent behaviour. Major AI researchers and textbooks define this field as "the study and design of intelligent agents", in which an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success. John McCarthy, who coined the term in 1955, defines it as "the science and engineering of making intelligent machines". The recent boom in this field and gives hope to AI enthusiasts about the future of intelligent machines.

The proposed methodology makes use of image processing for the purpose of flaw recognition in the input image which in this case is a human bone. The technique shall be able to recognize both major fractures and minute hairline/stress fractures. Existing technology makes use of strictly Canny-Edge detector or Hough transform. The main disadvantages are:

1) In Canny-Edge detector, most of the major fractures are detected. Hence if we try to further optimize it, the algorithm shall not be able to differentiate between a joint edge and a fracture edge.
2) If the algorithm is optimized to an extent where it can detect hairline fractures (achieved by increasing the sound filtering), the algorithm shall become highly inefficient and shall even detect the curves of bones as fractures.

This trade-off has been taken care of in this paper by combining the Canny Edge detector with a Hough transform. The purpose of the Hough transform is to find the angular orientation of the bones and bone pieces (in case of fractures) in order to recognise whether or not the bone is broken.

4.1 Architecture and Algorithm



The above flow diagram explains the flow of the procedure used in the code.

The algorithm is as follows:

1. Feed input from internet or computer path.
2. Convert image from RGB to Gray.
3. Image is de-noised.
4. Cany technique used to perform edge detection.
5. Hough transform performed to calculate angular orientation of bone pieces.
6. Results of Hough transform detection plot on a graph.
7. Multiple peaks detected based on major angle contributions.
8. No. of peaks = No. of breaks + 1.
9. If (no. of peaks > 1)

1. Convolute edge image with line of detected angle.
2. Difference between convolution images is calculated. If value > 0, breakage detected.
3. Centroid calculated at region of breakage to calculate bounding ellipse using major and minor axis.

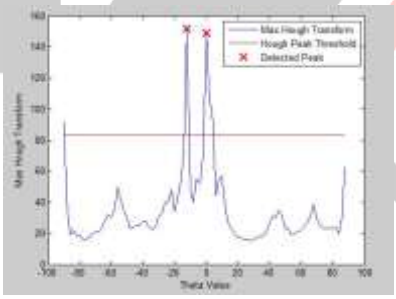
10. Else
    1. No breakage detected.
11. Ellipse is formed using bounding value calculated.

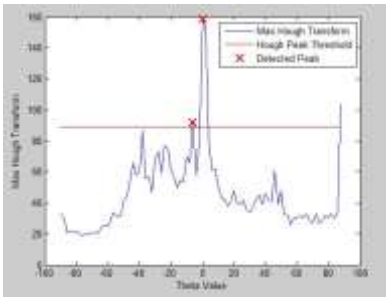
4.2 Results

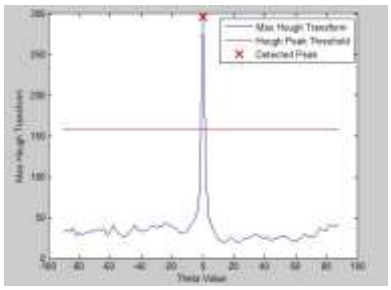
We have made use of an existing technique viz Canny-Edge detector in order to recognise the edges in the image.
The main disadvantage of the previously used Canny-Edge detector was that because of using just the edge detector and the Gaussian filter, the algorithm was not robust enough to detect minor stress and hairline fractures despite being able to detect major bone flaws. [2]
In order to overcome this problem, we have made use of a Hough Transform which as earlier mentioned is a feature extraction technique used in machine learning and pattern recognition systems.
In order to extend the work beyond the present set of results, a methodology called SVM has been introduced which is a kernel based supervised machine learning technique used for the purpose of classification.

5 FINAL RESULTS

Here are screenshots of the working of the bone fracture detector, which is a code made in Matlab. The figure includes samples of broken and unbroken bones being appropriately detected:







6 FUTURE SCOPE

Machine Learning can be used to classify the organs as fit or unfit by making use of certain predefined features such as depth, size, shape, etc. If that is achieved, the algorithm can be further strengthened by the introduction of stochastic grammar.
Let the various flaws of each organ be the children nodes. We can define the parent AND and OR nodes as the diseases and map the children nodes to the appropriate parents.
This can majorly be used in serious diseases such as Cancer, in which diagnosis takes as long as weeks. This approach would diagnose a patient in a few minutes.

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