Volume 2, No. 4, April 2011
Journal of Global Research in Computer Science
ISSN-2229-371X
RESEARCH PAPER
Available Online at www.jgrcs.info

An Edge Detection Algorithm for Human Knee Osteoarthritis Images

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Abstract: Digital image processing comprises varieties of applications, where some of these used in medical image processing include convolution, edge detection as well as contrast enhancement. Efficient edge detection depends on choosing the threshold; the choice of threshold directly determines the results of edge detection.
Osteoarthritis **(OA)** results from a failure of cells within the joint to maintain the balance between synthesis and degradation of the extracellular matrix. OA is a major cause of pain and disability in the elderly yet there is at present no effective treatment for loss of joint function. This is partly because the condition is heterogeneous with obscure pathogenesis but also because there are no specific laboratory tests or screening procedures that provide a specific diagnosis of early OA. There is a clear need to be able to define onset of characteristic pathological changes when intervention would be timely and to monitor the natural history up to the stage of Radiological detected damage.
In this paper, edge detection operator and its enhanced algorithm is used to detect edges for human knee osteoarthritis images in different critical situations. It is shown that the algorithm is very effective in case of noisy and blurs images.

Keywords: edge detection, knee osteoarthritis

INTRODUCTION

OA is a highly prevalent chronic health condition that causes substantial disability in late life. It is estimated that ~80% of the population over the age of 65 have radiographic evidence of Osteoarthritis, and given the prolonged life expectancy in the United States and the aging of the "baby boomer" cohort, the prevalence of Osteoarthritis is expected to increase further.

The human knee is a delicate and complex articulated structure that plays a vital role in the human motion system. Knee motion is coupled with the motions of four rigid bones including the femur, tibia, fibula and patella, as well as the deformations of muscles and ligaments surrounding the knee. Unfortunately, injuries to and diseases of the musculoskeletal system [1-3], for example caused by sports, metabolic disorder and cerebral palsy, usually lead to partial or total dysfunction of the components of the knee. Methods to assess knee parameters have been proposed to allow clinicians to make better evaluations of knee dysfunction [4-5]. Therefore, developing an objective and reliable method to measure these parameters has become an important issue.

MRI of the knee is acquired from eight subjects to develop an automated segmentation approach. The regions of interest (ROI) were femur, tibia, and patella cartilage.

Although newer methods, such as MRI, offer an assessment as well as articular structures, the availability of plain radiographs makes them the most commonly used tools in the evaluation of OA joints, despite known limitations in detecting early disease and subtle changes over time.

Since the parameters used for OA classification are continuous, human experts may differ in their assessment of OA, and therefore reach a different conclusion regarding the presence and severity. This introduces a certain degree of subjective ness to the diagnosis [6-7], and requires a considerable amount of knowledge and experience for making a valid OA diagnosis.

Due to the high prevalence of OA, there is an emerging need for clinical and scientific tools that can reliably detect the presence and severity of OA. Researchers proposed a computer-aided method of grading hip Osteoarthritis based on textural and shape descriptors of radiographic hip joint space, and showed 95.7% accuracy in detection of hip OA using a dataset of 64 hip X-rays (18 normal and 46 OA). Other researcher [8-9] described a convex hull-based method of detecting anterior bone spurs (osteophytes) with accuracy of ~90% using 714 lumbar spine X-ray images. Someone [7] proposed a system that monitors for changes in finger joints based on a set of radiographs taken at different times, which can detect changes in the number and size of osteophytes.

However, despite the prevalence of knee OA, computer-based tools for OA detection based on single knee X-ray images are not yet available for either clinical or research purposes. Here we describe a method for edge detection of OA by using computer-based image analysis of knee X-ray images. While at this point we do not suggest that the proposed method can completely replace a human reader, it can serve as a decision-supporting tool, and can also be applied to the classification of large numbers of X-rays for clinical research trials.

Two common clinical signs of knee disease are patella alta and patella baja [8-15], which can be evaluated by referring to the patella position on a lateral knee x-ray image. The signs are clinically important because it was reported to correlate with patellofemoral alignment and changes in contact area during weight bearing that might result in chondromalacia [16-18].

This manual process is laborious and can take up to 1 hour for each patient scan. It is also subject to the judgement of the clinician and requires significant experience and training to produce accurate and reproducible results. Thus, there is a strong demand for an improved automated method that will segment and measure the volume/surface area of articular cartilage in the human knee joint from MRI scans.

Osteoarthritis is the most common form of arthritis and involves the gradual loss of articular (joint) cartilage. It affects about 14% of the adult population [3] and is most prevalent in the knee and hip joints. Recent studies have shown that the quantitative measurement of knee cartilage volume is an accurate and reproducible method for the measurement of osteoarthritis progression [19].

Current methods of cartilage volume measurement involve some form of manual segmentation carried out by a trained clinician. The key steps in the segmentation process involve delineating the cartilage and separating it from the surrounding tissues. Images of a patient's knee are obtained using magnetic imaging resonance (MRI) with fat-suppression to provide the best contrast between cartilage and bone. The scans obtained are usually grey scale images in the sagittal plane and consists typically of 60 images (slices) for each knee. Using some form of medical/imaging software, the clinician will visually inspect and identify the presence of cartilage on each image slice.

REVIEW WORKS

Early-developed methods related to automatic landmark localization on x-ray images can be roughly divided into two categories: neural network-based and model-based methods. Researchers presented several neural network-based localization methods for cephalometric landmarks from x-ray images based on different machine learning approaches, including neuro-fuzzy system, multi-layer perceptron and least-squares function approximator.

These learning systems were trained to learn the spatial relation between some predefined geometric features (e.g. size and orientation) and landmarks of the skull from a set of training images. The system, after training, can then be applied to an input image for estimating the landmark locations. Nevertheless, the performance of neural network-based methods quite depends on predefined geometric features. As the knee is an articulated structure, each knee bone segment supports an individual way of movement, and furthermore, the ISR is related to the landmarks on more than one bone segment. The relation between the knee structure and landmark locations among different lateral x-ray images is thus unsteady due to various knee poses. Selecting geometric features for consistently describing the relation hence becomes quite challenging, making the neural network-based methods less appropriate for localizing landmarks on articulated structures.

The active shape model (ASM) introduced by Cootes and Taylor [3-5] and was a typical model-based method for localizing anatomical landmarks. The ASM represented a target structure by a parameterized statistical shape model obtained from training. By iteratively fitting the shape model to the boundary of the target object, the locations of desired landmarks can be estimated. The ASM-based methods are similar to the neural network-based methods in some sense; in order to achieve a stable localization process, both of them acquire some prior knowledge, implying the relations between specific geometric features and landmark locations through a learning process. Unfortunately, as the solutions are searched only in a local neighbourhood while using the ASM-based methods, these methods are very sensitive to the pose of the initial model. If the shape model is initialized far from the object of interest, the searching process tends to be slow or even fail. However, by reason of the ASM's high flexibility on interpreting object shapes, the ASM is still popular in developing image-based methods for anatomical structure analysis.

Most of the research on anisotropic diffusion over the years has been focused on the preservation of features in the image while denoising the image data. Anti-geometric diffusion is a form of anisotropic diffusion that goes against this trend by diffusing across image edges, in a direction orthogonal to the geometric heat flow. Geometric heat flow diffuses along image edges, thus preserving the edges while anti-geometric diffusion effectively spreads out the edge information. The method is thus termed anti-geometric because it is orthogonal to the geometric heat flow.

PROPOSED METHOD

The advantage of smearing edge information is that it allows quick detection of features and their location within an image, thus enabling fast segmentation of the image. Image regions that lie nearby, but on opposite sides of a prominent edge are quickly distinguished.

Edge directions are usually related to the tangents of the isointensity contours (level curves), since the tangent direction of an isointensity contour is the direction perpendicular to the image gradient.

Algorithm

In this paper we have proposed a new method for detecting edge rather than using one of the known methods of edge detection. In the first step of our proposed method we perform horizontal scanning. If any change of pixel intensity is observed it is marked by a black pixel indicating a horizontal edge point. We continue this process for all rows of pixel data to obtain a Horizontal Edge Map. In the next step, we scan the image vertically. Continuing the process for all the columns we obtain a Vertical Edge Map image. Finally, we merge the Horizontal Edge Map with Vertical Edge Map by performing a logical OR operation on the two image files, to obtain the Edge map of knee image.

Algorithm for Horizontal Image Map:

Scan the Image Array Horizontally from left-most pixel to right-most pixel from first row to last row.

Take the first pixel intensity value as a reference value.

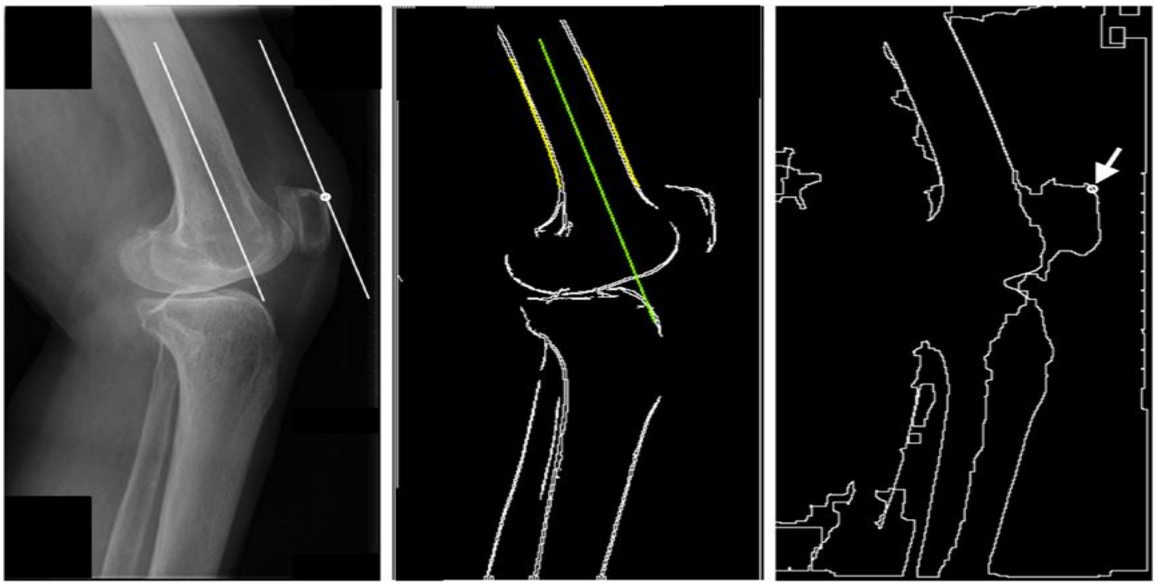
Compare intensity of subsequent pixels with the reference value. If the value is same continue to next pixel.

If the value differs, change the value of reference value to the pixel intensity value and mark the pixel black.

If the last row and column pixel is not reached then Goto Step3.

ALGORITHM FOR HORIZONTAL IMAGE MAP

The same process, as mentioned above, by replacing row wise scanning with column wise scanning starting from top-most pixel to bottom-most pixel from first column to last column and continue untill the last column and row pixel is not reached. The output is shown below (Figure 1).



(a) (b) (c)

Figure 1. Patella feature point extraction: (a) illustration of the patella feature point (empty circle) on the x-ray image; (b) the resulting femur dominant axis; (c) Detection of Edge

CONCLUSIONS

Images are very important parts of medicine which are frequently used by physicians and doctors to investigate and diagnose of the structure and function of the body. In this paper, an automatic edge detection method is proposed for medical images. It is similar to region growing algorithm where the seed points are automatically selected and grown.

In the proposed algorithm, similarity percents of the pixels were calculated by using the amount of shift while the occurred light through a transparent sheet and re-enters the same environment.

The proposed edge detection algorithm does not require any prior knowledge of the number of regions existing in the image. Therefore, it reduces the computational complexity required by the other image methods. The experimental results show that the proposed algorithm gives sufficiently good results.

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