Review of improvement of accuracy in analysis of articular cartilage

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***Abstract*— The automatic segmentation of medical imagery is a difficult problem for which no generic solution can be expected in the near future. In order to improve the reliabilityof cartilage delineation from MR scans of knee, a tool is there that performs automatic segmentation of patellar cartilage. The same tool also implements manual and semi-automatic methods of interacting with the segmented structures, thus supplying fast and simple means of correcting any eventual inaccuracies that may affect the automated process. Also, a customized registration algorithm was developed that can be used, alone or in conjunction with the automatic segmentation, for estimation of the deformations that occur in the patellar cartilage during in vivo compression experiments. In the following, the description of the main features and implications of the proposed frameworks is done and give an outlook on directions that should be further investigated.In this paper first we represent an overview of knee joint and discuss the methodology and functioning. Thereafter we represent techniques which are recently used. A large number of analysis of knee joint algorithms have been developed. In this paper an attempt is made to review a wide range of methods including automatic segmentation, customized registration, rigid registration and combination if this techniques.**

Index Terms— **MRI, Osteoarthritis, Knee joint, Image segmentation,registration.**

I. INTRODUCTION

The knee joint is the largest and most complex synovial joint of the human body. It is a major weight bearing joint of the body made up of condoles of femur, condoles of tibia and patella's posterior surface. An articular cartilage is a thin layer between the femur and tibia bones. It is a soft tissue at the end of bones that allows the joint to move freely. The knee joint contains a small amount of fluid in a cavity that lubricates the cartilage called synovial fluid. Osteoarthritis is a common disease of the knee joint affecting the elderly people. It occurs when cartilage becomes soft and gets eroded due to continuous wear and tear movements and with ageing. The OA affected knee joint leads to inflammation, due to stiffness motion of joint decreases, and formation of bone spurs. The ability of the cartilage to work as a shock absorber decreases to reduce the impact of stress on the joints. Cartilages allow the bones to slide freely on each other. In the last years magnetic resonance has been established as a valid and completely non-invasive method for mapping the internal structure of the body, and is now used routinely for joints. After acquisition appropriate software is needed to correctly process and visualize the images. Among the pathologies of the knee the cartilage is one of the most important. It is necessary to segment the cartilage elucidating its boundaries with the surrounding anatomic structures. The more common and easy implemented approach to solve this problem is interactive segmentation, because the morphology of the knee makes it too difficult to use automated algorithms. The present work is a contribution towards a completely automatic procedure, which automatically improves the results obtained, with interpolation algorithms using radial functions to interpolate pixel values. The generation of three-dimensional (3d) knee model from patient-specific medical image data is important for the diagnosis, pathology localization, planning of treatment, and computer-integrated surgery. The reconstructed 3d knee model would be used to visualize and analyze the dynamic and kinematic behaviours of the knee joint. This paper provides a discussion of current segmentation techniques for knee joint from medical imaging, such as computerized tomography (CT) and MRI (Magnetic resonance imaging). Segmentation methods and their applications of knee joint from recent literatures are described and discussed. The automatic segmentation of medical imagery is a difficult problem for which no generic solution can be expected in the near future. In order to improve the reliability of cartilage delineation from MR scans of the knee, a tool is there that performs automatic segmentation of the patellar cartilage. The same tool also implements manual and semi-automatic methods of interacting with the segmented structures, thus supplying fast and simple means of correcting any eventual inaccuracies that may affect the automated process. Also, a customized registration algorithm was developed that can be used, alone or in conjunction with the automatic segmentation, for estimation of the deformations that occur in the patellar cartilage during in vivo compression experiments. Injury of the joint can lead to cartilage degradation, which can be better monitored and treated once accurate information about the shape and structure of the cartilage is gathered. Also, it is known that the articular cartilage of load-baring joints shows progressive thinning in case of long periods of immobilization [1]. Hence, monitoring cartilage responsiveness to motion and loading of the joint can help the development of physical therapies for prevention of cartilage atrophy due to immobilization. Based on the degree of movement that they provide, articulations encountered in a human skeleton can be classified into three groups:

1. Immovable, when the articulating bones are directly united with a band of fibrous connective tissue (synarthrosis); e.g. articulations of the skull, joints that fit the teeth into the maxillar, etc. Slightly movable, when there is much more fibrous connective tissue than in synarthrosis, and so the fit between the bones is not so tight and allows some movement at the joint (amphiarthrosis).

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2. Freely movable, when the bones are connected through ligaments and joint capsules, therefore they can produce a diversity of movements (diarthrosis).

II. Literature Review

Osteoarthritis (OA), a common cause of disability in the aging population, is a complex, heterogeneous condition which is associated with degradation of articular cartilage. Until recently, treatment and assessment of symptomatic knee OA have focused on clinical parameters and x-ray radiographs. This approach is limited, however, and does not allow us to evaluate the effect of treatment early in the disease process, when there are structural changes involving multiple tissue components. Advances in MR imaging and quantitative image analysis have recently contributed to the generation of a wealth of information on tissue structural changes. The Osteoarthritis Initiative (OAI), funded by a public-private consortium, was launched to identify biomarkers of the development and/or progression of knee OA. The most important issue regards the biological behaviour and the responsiveness of articular cartilage to injury and immobilization. Detection of inflammation, ruptures and thinning of the cartilage provide considerable support for prevention and early diagnosis of OA.

The concept that OA is a dynamic pathological process has resulted in the possibility of new treatments. As current methods for OA may not have good sensitivity. Selection of the appropriate technique depends on the development of better methods of assessing and tracking OA.

Once an image of some anatomical part of the human body has been acquired, it must be interpreted by a medical expert. Usually, the first step in the interpretation process consists in identifying the physical objects depicted in the image and is known as segmentation. In the case of medical imaging, the objects are anatomical structures such as bones, ligaments, cartilages, soft parts and organs. The classification of image segmentation techniques are done in: pixel and geometry-based methods:

1. Pixel-based algorithms directly implement the basic concept of segmentation as defined by[2] i.e. combining adjacent pixels with "similar" image characteristics into homogeneous regions called "segments". The similarity of neighboring pixels can be determined by means of various image characteristics that depend largely on the locality of the employed feature operators. The simplest image features that are used for this purpose are the basic pixel values.
2. Geometry-based segmentation is complementary to the pixel-based, in a manner that it employs a top- down technique for classifying image pixels. Such methods have found in recent years widespread use in computer vision and medical imaging. Segmentation methods that fall into this category start with a generic description of the object to be segmented. The object model is then deformed, usually during an iterative process, until it matches the information present in the image to be segmented.

It was shown that in today's clinical practice, the first step in the process of analyzing the information supplied by a medical imaging device is the identification of the anatomical structures that are under investigation. Once an anatomical structure is identified, a medical expert continues the analysis by comparing it either with a normal, healthy instance of the same organ or to other instances of the same organ from the same subject, taken at previous times in the past. The first case is mainly used during diagnosis, when the physician looks for pathological changes in the shape or internal structure of the organ, while the other method is used for monitoring the evolution of the disease and the effect that various treatments have on it. In order to perform a comparison, a similarity must be identified between different sub-parts that compose each instance. The general task of finding correspondence between different data sets is known as registration. In medical imaging, the correspondence is defined from the anatomical point of view and to date there exists a large number of registration algorithms [3]. A more recent survey of image registration methods, including medical image applications, was given by [4]. This section addresses the registration problem from the medical imaging point of view. The most popular medical image registration problems are surveyed and the most important computing methodologies for solving them are presented. Based on the elasticity of the transformation used in the process, we can classify registration techniques in rigid and non-rigid.

a) Rigid registration is applicable provided that the deformations sustained by the anatomy are negligible compared to the required accuracy of the transformation.

b) Non-rigid registration. If the deformations between different acquisitions are good and if these deformations are caused by factors other than noise and distortion within the modality, then a non-rigid transformation must be employed. Non-rigid registration can use affine, projective and curved transformations. If the type of the data to be registered is used as a criterion, we obtain two categories of registration methods:

i. Image-based registration establishes a pixel-wise correspondence between two or more images. The images can be two-dimensional slices or three-dimensional volumes.

ii. Surface-based registration is performed on surface representations of anatomical structures, usually segmented organs. Using this type of methods, the correspondence between the components of the employed surface parameterization are obtained.

III. Discussion

The spline-based semi-automatic segmentation method relies on stacks of spline curves for reconstructing the 3D volume of the object of interest. The control points of these splines are iteratively adjusted so as to adapt the curves to the object being segmented. The M-REP-based segmentation technique uses a different representations of the spline curves, in order to achieve better processing time in the case of articular cartilage structures. By exploiting the sheet-like shape of the cartilage, this method performs a hierarchical adjustment of a medial representation of the boundary curve. Automatic segmentation aims to completely eliminate human interaction from the whole segmentation process. Consequently, better reproducibility is expected from such a method, which may come with some loss in accuracy. Additional work has to be done in order to improve the robustness of the automatic segmentation algorithm that was presented in this thesis Currently, our segmentation program includes manual and semi-automatic tools for correcting the possible inaccuracies that may occur.

IV. CONCLUSION

The main subject of this is, the improvement of accuracy in analysis of articular cartilage by automatization of segmentation and registration, has been approached. The existing collection of semi-automatic and automatic tools for cartilage analysis has been enriched with two new methods that focus on the patellar cartilage.

We have seen that the automatic segmentation of medical imagery is a difficult problem for which no generic solution can be expected in the near future. In order to improve the reliability of cartilage delineation from MR scans of the knee, we have developed a tool that performs automatic segmentation of the patellar cartilage. The same tool also implements manual and semi-automatic methods of interacting with the segmented structures, thus supplying fast and simple means of correcting any eventual inaccuracies that may affect the automated process. Also, a customized registration algorithm was developed that can be used, alone or in conjunction with the automatic segmentation, for estimation of the deformations that occur in the patellar cartilage during in vivo compression experiments.

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