A fast method for finding maximum range of motion in the hip joint

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Introduction: For diagnosing some of the hip diseases, it is important to obtain the hip's range of motion. For example loss of internal rotation in the hip is one of the first signs of internal hip pathology and can be related to diagnoses, such as arthritis. Also, increase in femoral or acetablular anteversion usually demonstrates an increase in the internal rotation. Clinical hip examinations are usually based on rotating the hip in the special orientations. For instance, the flexion adduction internal rotation test is used to aid in the diagnosis of femoroacetabular impingement in the anterior location. Such practical methods are usually based on the patient's feedback during the examinations and therefore the diagnosis may not be easy and accurate [MAR05].

On the other hand, after diagnosing the hip disease, the treatment may be based on surgery. For example options for treatment of femoroacetabular impingement include trimming of the anterior aspect of the acetabular rim, and surgical resection of part of the anterolateral aspect of the neck. Since the operation can be highly invasive, it is essential that surgeon has knowledge of maximum range of motion before operation to know exactly about the surgery strategy and reduce the risk of miss-operation [MGC05].

Having a computer aided method for finding the hip's range of motion can help us to have a more accurate diagnosis and/or surgery strategy. The computer aided methods for hip simulations usually exploit the reconstructed 3D model of the hip tissues obtained from MRI. The traditional methods for finding range of motion are based on repetitive collision detection for numerous rotation steps until a collision happen, [KSMM03]. This can be highly time-consuming. We propose a novel method for finding maximum range of motion for hip joint based on cylindrical segmentation. The method is faster than traditional ones, and needs to be performed only once per axis orientation. This method is illustrated on the case of finding maximum range of motion in the human hip joint, which is not only useful for further hip simulation but also provides information about hip disease for surgeon.

Methods: The method works by segmenting the object spatial occupancy with cylindrical coordinates. At the first step we trim out non colliding parts by calculating distance between the rotating axis and different parts of the objects. In the next step the objects are cylindrically segmented. The corresponding ring-shaped sampling cells (see Fig.1) are optimal for conducting collision detection for the associated axis of rotation. One table is filled per object where a table cell represents a complete cylindrical segment (i.e. a ring). A cell stores the list of all the cylindrical angular intervals spanned by intersecting polygons. Then for each ring, we find the smallest angular distance between parts of the moving object and parts of the fixed object. This method is done for all the rings. The smallest angular distance among all the rings is found to be considered as the maximum range of motion for the object pair without the need of performing any direct collision detection.

Results: We applied the proposed method to the human hip joint. In the current work our tests were based on finding the bone to bone maximum range of motion. We used 3D triangular meshes obtained by segmenting MR Images taken from a patient [GMM06]. The center of rotation was also found based on the scanned 3D models [KSMM03].
The results showed that the sole initialization stage of a traditional method takes a longer computational time than the 'total' computation time in our method (it could be up to more than 2.3 times slower). It is obvious that after initialization in the traditional method, the main process of collision detection must be performed several times until a collision happens, which can make the process much slower than our methods.
The method was also applied for different orientations of the rotational axis in the hip joint (see Fig.2), and we could obtain the maximum range of rotation for the different orientations of the hip's rotational axis. The interpolated curves can be used by a doctor to diagnose the problem of joint especially if the range of rotation is found by considering cartilages in order to illustrate the effect of cartilage's bumps too.

Discussion: We proposed a novel method for finding the maximum range of motion in rotational cases based on cylindrical segmentation. The method showed to have less complexity than traditional methods, and needs to be performed only once per simulation. The method was tested on the case of finding the maximum range of motion in the human hip joint. These experiments proved that the proposed algorithm is faster compared to the previous methods

and can be used essentially for the musculo-skeletal simulation for diagnosing hip diseases or validating the surgery strategy.
As a future work, in case a more exact range of motion is desired, we should rotate the possible colliding polygons in the moving object about the estimated range of motion, and test whether these polygons are colliding or not. Also it is useful to perform more tests on a more complicated hip capsule (containing more tissues) to make the method fully suited for clinical applications.

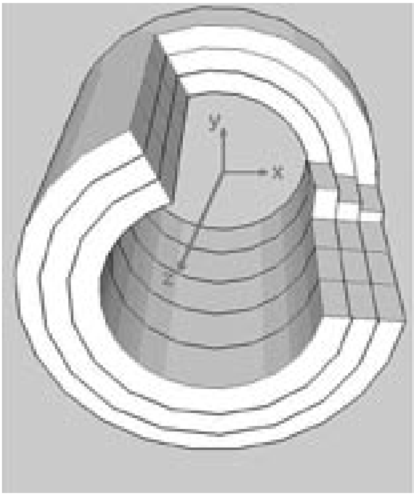

Figure 1

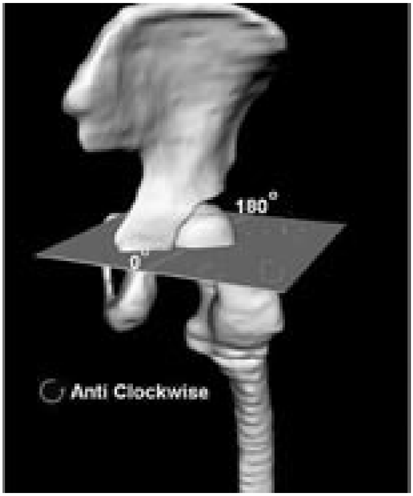

Figure 2

Acknowledgment
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