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AUTOMATIC 2D-3D DETECTION AND SEGMENTATION OF SPHERIC AND ASPHERIC FEMORAL HEADS IN MR IMAGES USING HOUGH TRANSFORMS

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Abstract

In most of the computerized analysis and assessment cases of the hip joint, segmentation of the femoral head with the automatic or semi-automatic segmentation methods is an important issue. In this study, we aimed to perform 2D-3D detection and segmentation of the spheric and aspheric femoral heads automatically in MR hip images of patients with Legg-Calve-Perthes disease (LCPD) by using the Circular and Spherical Hough Transforms. Successful results were achieved with the proposed methods.

Introduction

Hip and hip joint elements have a quite importance and functionality in body movement and stability in human skeletal system. Femoral head shape structure and functionality can be affected by a wide range of hip disorders such as coxarthrosis, LCPD, slipped capital femoral epiphysis and femoroacetabular impingement. Recent studies, which have been conducted by research groups in field of medical image processing in order to analyze the degeneration of femoral head [1] and assess the severity of the diseases [2], are mostly related with the segmentation [3,4] and statistically shape modeling of the bone and cartilage tissue [5].

Materials and Methods

Legg-Calve-Perthes Disease

LCPD is an early childhood hip disorder with its unclear etiology in pediatric orthopeadics [6]. Due to ischemia arises in femoral head, avascular necrosis occurs in femoral head ball. With the fractures of cartilaginous tissue in the femoral head and the collapses in the bone tissue, the global structure of the bone is deteriorated and femoral heads are flattened.

Materials

Dataset – 1 (2D)
13 patients (12 male,1 female)
Mean age: 7.89 (±3.59)
Mean weight: 48.46 (± 28.02)

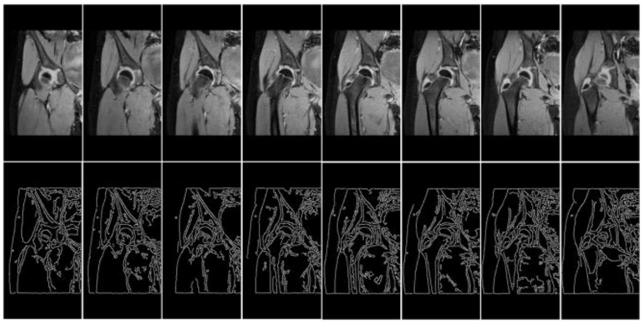
24 MR image sections with different imaging protocols. 1.5 T MR scanners (Philips Medical Systems, General Electric Medical Systems).

Dataset – 2 (3D)
6 patients (all male)
Mean age: 7.82 (±3.82)
Mean weight: 34 (± 15.23)

8 MR image sequences with different imaging protocols. 1.5 T MR scanners (Achieva and Intera, Philips Medical Systems)

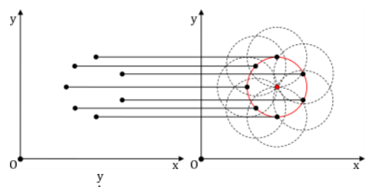
Methods

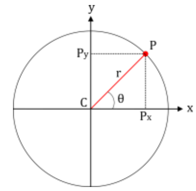
Divide MR image sections vertically → Obtain edges with Canny's method → Apply Circular Hough Transform or Sperical Hough Transform



Materials and Methods

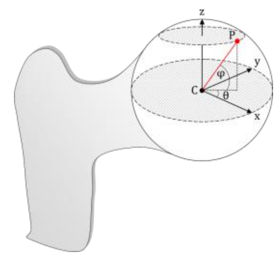
Circular Hough Transform (CHT) [7]





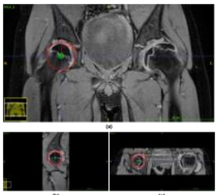
$$P_x = C_x + r \cdot cos(\theta)$$
$$P_y = C_y + r \cdot sin(\theta)$$

Spherical Hough Transform (SHT) [8]



$$P_x = C_x + (r \cdot cos(\varphi) \cdot cos(\theta))$$
$$P_y = C_y + (r \cdot cos(\varphi) \cdot sin(\theta))$$
$$P_z = C_z + (r \cdot sin(\varphi))$$

Experimental Results



$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(A_i - P_i)^2}$$

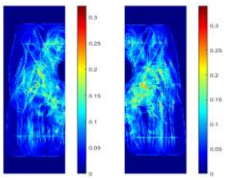
$$DSC(C_A, C_P) = \frac{2|C_A \cap C_P|}{|C_A| + |C_P|}$$

$$DSC(S_A, S_P) = \frac{2|S_A \cap S_P|}{|S_A| + |S_P|}$$

In order to evaluate the performance of the proposed methods, we measured two evaluation metrics. First one is the root mean square error (RMSE), which is used to calculate the error of the actual and predicted center coordinates and radii which were measured in terms of mm.As the second evaluation metric, we utilized Dice similarity coefficient (DSC).

Dataset – 1 (evaluated for CHT)
We observed 2.28 (±1.49) mean RMSE for center coordinates, 1.63 (±1.46) mean RMSE for radii, 0.8853 (±0.0868) mean DSC on healthy femoral heads and 4.23 (±3.66) mean RMSE for center coordinates, 1.71 (±1.35) mean RMSE for radii, 0.8253 (±0.0937) mean DSC on pathological femoral heads.

Dataset – 2 (evaluated for SHT)
We observed 2.14 (±1.74) mean RMSE for center coordinates, 0.84 (±0.56) mean RMSE for radii, 0.8992 (±0.0608) mean DSC on healthy femoral heads and 5.53 (±4.29) mean RMSE for center coordinates, 0.71 (±0.36) mean RMSE for radii, 0.8006 (±0.1355) mean DSC on pathological femoral heads.



Conclusions

In this study, we addressed the problem of spheric and aspheric femoral head detection and segmentation in bilateral hip MR images of patients with LCPD using the Circular Hough transform (CHT) in 2D and Spherical Hough Transform (SHT) in 3D automatically. MR image sequences of patients were acquired in coronal plane by performing different MR imaging protocols. Slices in each MR image sequence were automatically divided into two equal rectangular halves vertically in order to evaluate left and right femoral heads separately. We performed Canny's edge detection method to obtain the edge information. Finally, CHT and SHT were employed on edge images for detection of healthy and pathological femoral head balls. Performance evaluations on two datasets show that proposed methods have promising results in spheric and aspheric femoral head detection, segmentation.

References

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