Developing Computer Programming Techniques to Calculate the degree of Developmental Dysplasia of the Hip (DDH) in Children

Mafaz Mohsin Khalil
Master of Computer Science Assistant Teacher in College of Science – Biology-Uni. of Mosul
(Received / / 2007, Accepted / / 2008)

Abstract

The goal of this study, is to use Mask Technique and Center Detection for developmental dysplasia of the Hip (DDH) diagnosis [7] which aims at calculating center and diameter of Head of Femur to diagnose some of the effects of Developmental Dysplasia of the Hip (DDH) on the hip joint.

This study uses the Mask Technique and Center detection to complete the calculation of the acetabular angle and the distance of the head of femur from acetabulum. These two new criteria give the doctor very valuable information in the diagnosis of DDH and its degree.

An algorithm is designed to do the following steps:

1. Exploring the details of the X-Ray and cutting out the necessary parts (acetabular bone and head of femur) for the desired side (right or left) instead of using the complete image.
2. Enhance the cropped parts by using Contrast linear stretching, Median filter and Canny edge detection.
3. Search for the center of the head of femur and calculate its diameter.
4. Measure the angle of acetabular bone and measure the distance from head of femur to acetabular bone.

At last the features are extracted (Center of head of femur, Intensity value of the center, Diameter of head of femur, angle of acetabulum and distance from head of femur to the acetabulum, place in acetabulum bone). We applied this system in computer using Matlab 7.0 programming Langue.

Introduction

Congenital Dislocation of the Hip (CDH) is the old name and we depend here on the new name Developmental Dysplasia of the Hip (DDH) [3]. This is a common abnormally that affects hip joints in newborns leading to various degrees of displacement of femoral head from its socket.

The diagnosis of DDH using conventional x-ray films represents a challenge to the clinician especially when the amount of displacement of the femoral head from its socket (the acetabulum) is borderline.

Several parameters were, for this reason, established to assist in diagnosis. Most of these parameters depend on measurement of distances and angles or even naked eye appreciation with the resultant bias due to inter-observer variations [2], Figure (1).

There are two important features that are useful for diagnosis and for the purpose of classification and grouping of hip abnormalities in DDH: [3]

1. Lateral displacement of femoral head.
2. Acetabular angle of inclination.

Figure (1): diagrammatic illustration of measurement of acetabular angle.

DDH Segmentation Algorithm

The steps of DDH segmentation algorithm are six as follows:

1. **Read X-Ray image, Figure (2).**
2. **Crop acetabulum.**

In Matlab version(7), this instruction could be used to do this job:

Bw = imcrop (image)

- (image) is two dimensional array of the grey level image Congenital Dislocation of the Hip (DDH), as previously shown in Figure (2).
- (BW) is two dimensional array of grey level image that contains head of femur and socket (acetabulum), as shown in Figure(3).

Figure (2): The original image for bilateral DDH.

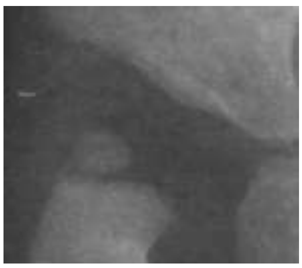


Figure (3): The acetabulum part for the right side.

3. Contrast linear stretching.

The job of this step of segmentation algorithms is to expand the narrow range of brightness values of an input image over a wider range of gray values then results in an output image that accentuates the contrast among the features of interest.

The formula that is used in this work of linear stretch is [5]:

$$DN_{cs} = \left[\frac{DN - MIN}{MAX - MIN} \right] 255$$

Where:

DN: is the original grey level image

MIN: is minimize the value of grey level in the image

MAX: is maximize the value of grey level in the image

DN_{cs}: is the result image of linear stretch contrast as shown in Figure (4)

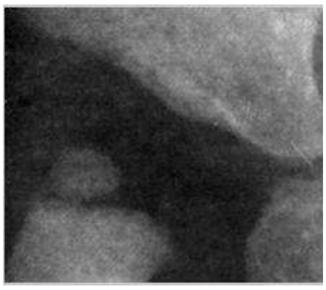


Figure (4): Linear stretch for the acetabulum part for the right side.

4. Smoothing.

Median filter is the technique that is used in this study to smooth image crop. Median filter is a nonlinear spatial based on the median brightness value of each input group of pixels [1]. In a set of ordered values, the median is the central values. The median of a set of number of two dimensional array is the value which is (50%) above and (50%) below so if a pixel is accidentally changed to an extreme value, it will be eliminated from the image and replaced by a reasonable value in the neighborhood as shown in Figure (5).

Median filter is one of the best edge preserving and smoothing filters. Its primary use is removing impulse noise spike from an image. Impulse noise spike appears as bright to dark pixels randomly distributed throughout the image. Because spikes are significantly brighter or darker than their neighboring pixels, they generally end up at the top of bottom of brightness ranking for a group of input pixels and so it is generally avoided and eliminate in the output image [1].

Input image

30	36	20
8	60	17
19	25	28

Median filter ⇨

Output image:

30	36	20
8	25	17
19	25	28

Figure (5): Median filter Technique.

Median filter reduces the burying of edge [4]. In this study, the median filter has been programmed to accept the square size of window while the executive time of program from user size of window can be (3×3) or (5×5), depending on the image of the different size of median filter that gives the system more accuracy to detect the edge of an abnormal region of image, as shown in Figure (6).

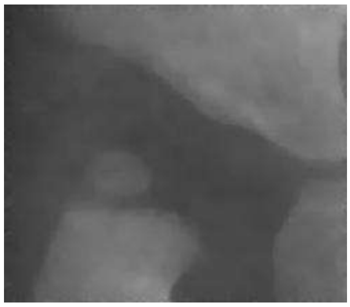


Figure (6): Median filter for the acetabulum part for the right side

5. Crop head of femur.

This step is completely like step2, but the result is sent to Head of Femur Detection algorithm (we explain it later in page 7) to calculate center and diameter of Head of Femur, as shown in Figure (7).

Figure (7): The cropped head of femur.

6. Canny edge detection.

You can use the edge function to detect edges, which are those places in an image that correspond to object boundaries. To find edges, this function looks for places in the image where the intensity changes rapidly, using one of these two criteria:

- Places where the first derivative of the intensity is larger in magnitude than some threshold
- Places where the second derivative of the intensity has a zero crossing

Edge provides a number of derivative estimators, each of which implements one of the definitions above. For some of these estimators, you can specify whether the operation should be sensitive to horizontal edges, vertical edges, or both. edge returns a binary image containing 1's where edges are found and 0's elsewhere.

The most powerful edge-detection method that edge provides is the Canny method. The Canny method differs from the other edge-detection methods in that it uses two different thresholds (to detect strong and weak edges), and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges [6]. Show Figure (8)

The result of this algorithm DDH segmentation is the head of femur and socket (acetabulum), without any background.

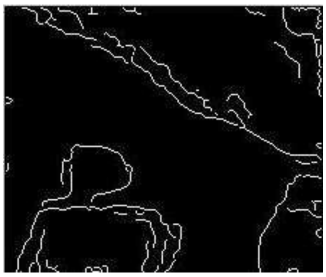


Figure (8): Canny edge detection for the acetabulum.

Head of Femur Detection algorithm

The X-Ray region taken for DDH is too large, so we capture the head of femur in a separate image. The head of femur is almost like a circle, therefore novel techniques are proposed using mask, profile and
Combination between them for detection of center of the head of femur. These techniques give high accuracy and reduce the execution time required to detect the head of femur.

Basically, the captured image has unadvisable space. This unadvisable space could be reduced by segmenting the head of femur image into (8×8pixel,64 pixel (8bits per pixel)) segments, Figure (9) (Note, we try another size of mask like (32×32pixel) and (16×16pixel) but we found mask (8×8pixel) has the better result).

The used search space is the segment that has the maximum average of intensity value. This reduced search space is used in the next head of femur center detection steps.

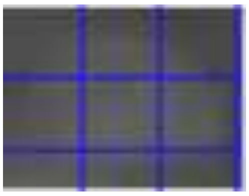


Figure (9): The reduced search space in a head of femur for the right side.

Head of Femur Detection Using Mask

After segmentation to reduce search space, the convolution process is applied using a mask (2×2) with ones coefficients. By this way we find the center [7].

Diameter Detection by Profile

The profile is a tool of an image processing technique. The profile of an image region is a projection of compact representation in the spatial pixel content distribution and has been successfully employed in this work. It is the set of intensity values taken from regularly spaced points along a line segment or multi-line path in an image. It could be applied for horizontal or vertical direction [7] [8].

A novel application is proposed for the technique of diameter detection by profile. The head of femur center is calculated by finding the maximum occurrence of an intensity value in the rows and columns. The center lies on white region; therefore the highest intensity value has the maximum occurrence in the profile. The column index of the maximum occurrence represents the *X* coordinate of the head of femur center. The row index of the maximum occurrence represents the *Y* coordinated of head of femur center. Figure (10) shows the center and the circle that we calculate diameter for it later.

Figure (10): Center and diameter.

The radius of the head of femur RAD as shown in the Figure (3) above, is calculated as the average of two calculated radii R1 and R2. The radius R1 is calculated from the minimum values of column profile compared with X coordinate of the center, denoted as COL_{min}. Then the radius R1 is calculated according to the following equation:

$$R1 = abs(X - COL_{min})$$

The radius R2 is calculated from the minimum values of row profile compared with Y coordinate of the center, denoted as ROW_{min}. Then the radius R2 is caculated according to the following equation:

$$R2 = abs(Y - ROW_{min})$$

Now, we have two radius values one for column R1 and another for row R2, The Diameter DIAM of the head of femur is calculated according to the following equation:

$$DIAM = R1 + R2$$

While, The radius RAD of the head of femur is calculated according to the following equation:

$$RAD = (R1 + R2)/2$$

Note, the diameter and the radius are in pixel, so we divide them on the resolution of images to obtain them in centimeter, but this size does not represent the real size of head of femur because it depends on how we picture the image (perspective effect), so we compute the percentage of diameter size between diseased and normal sides which is the most important feature for diagnosis.

Calculate the degree of DDH

After the two previous algorithms we have these important data:

1. Center of head of femur.
2. Diameter of head of femur.
3. Canny image as shown in previous Figure (8).

Note we adjust the calculated center to fit the new canny image dimensions.

At last the doctor or the user draw two connected lines beside the acetabulum bone, these two lines form an angle which the doctor desires to calculate, because it is very important for diagnosis of the degree of DDH. So that, we need to calculate the inclination for each line to calculate the desired angle which the doctor specify, and this is done by these series of equations:

$$M1 = \frac{y2 - y1}{x2 - x1} \qquad M2 = \frac{y3 - y2}{x3 - x2}$$

$$M1 = \frac{\Delta y}{\Delta x} = \tan \Theta 1 \qquad M2 = \frac{\Delta y}{\Delta x} = \tan \Theta 2$$

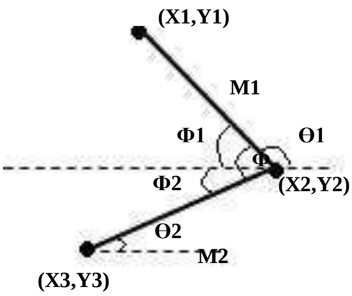
$\Theta 1 = \tan^{-1} M1$

$\Theta 2 = \tan^{-1} M2$

$\Phi 1 = 180 - \Theta 2$

$\Phi 2 = \Theta 1$

$\Phi = \Phi 1 + \Phi 2$



At last we draw a line started from the head of femur (from center minus half diameter) to the acetabulum bone, which represent the distance that the head of femur move away from his place in the acetabulum bone. Note that we measure this distance in millimeters. Figure (11) shows the two lines, angle of acetabulum bone, center of head of femur, diameter of head of femur and distance from head of femur to acetabulum bone.

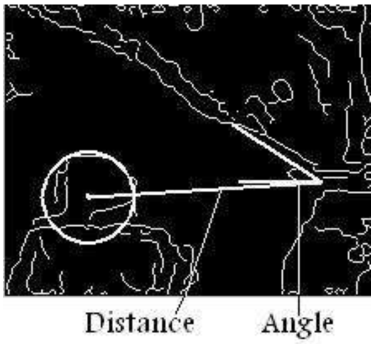


Figure (11): Angle of acetabulum bone and distance from circle of head of femur to acetabulum

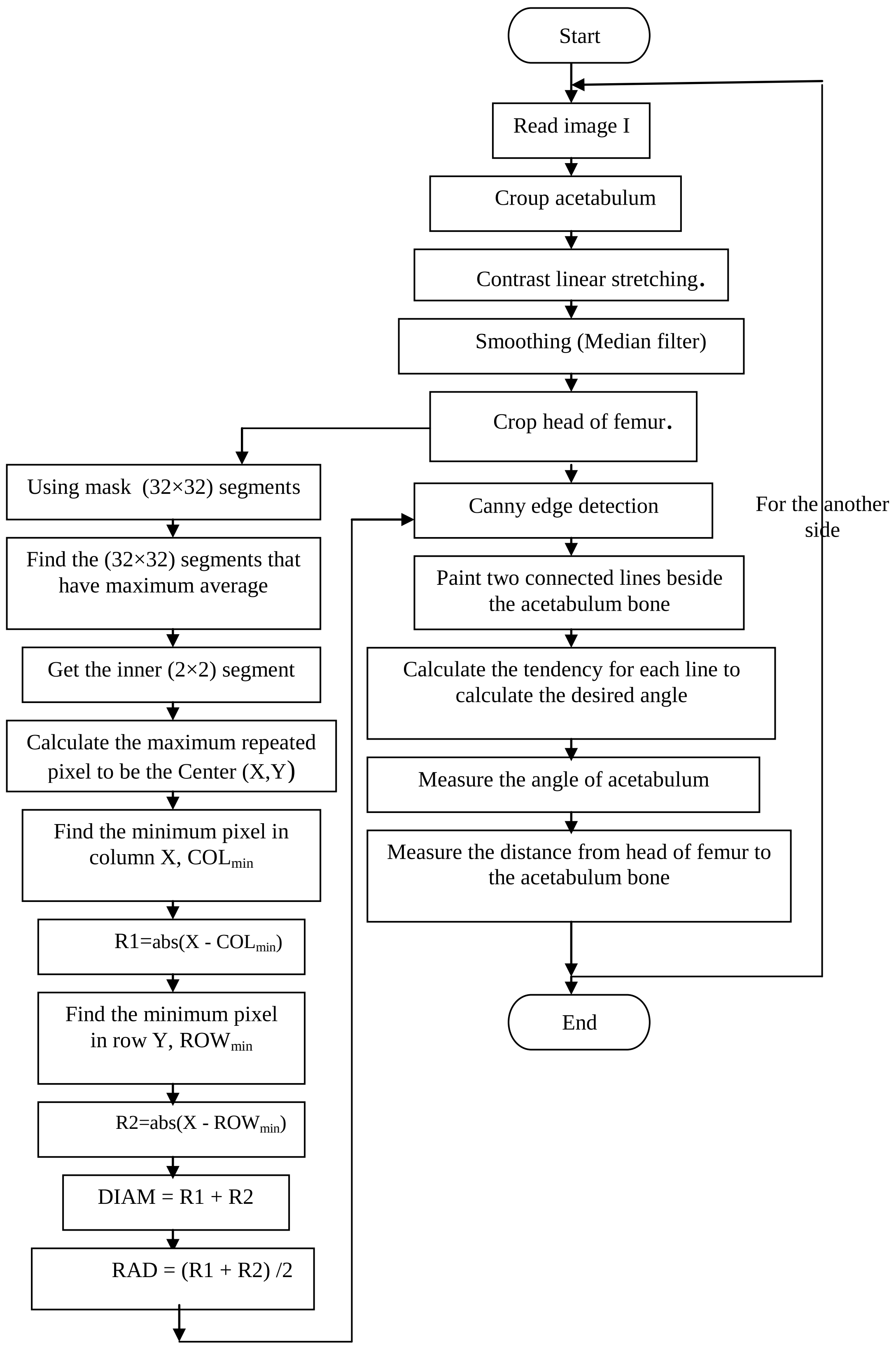


Figure (12): Flow chart of DDH Segmentation Algorithm, Head of Femur Detection algorithm and Calculate the degree of DDH.

Result

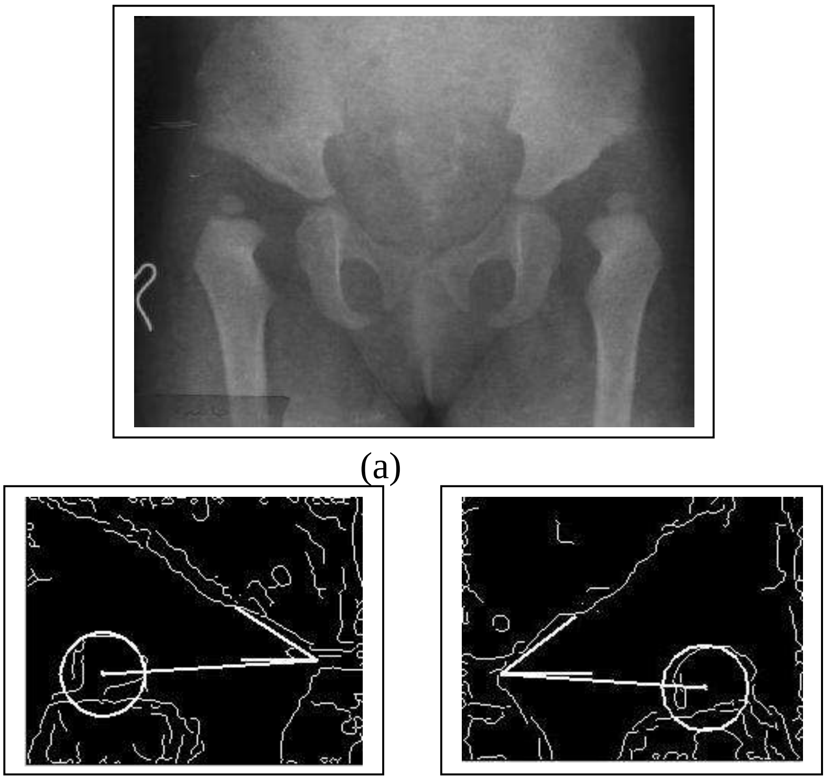
1. Image for bilateral DDH, Figure (13).

Right side result :

a. Canny = 1
b. Center (X,Y) = (51,118)
c. Center Intensity = 97
d. Diameter = 2.7556mm
e. Angle = 32.942 º
f. Distance = 30.7278mm

Left side result :

a. Canny = 1
b. Center (X,Y) = (160,141)
c. Center Intensity = 104
d. Diameter = 2.7653mm
e. Angle = 37.7939 º
f. Distance = 24.3724mm



(a)

(b) (c)

Figure (13): (a): Image for bilateral DDH. (b): Angle and distance for the right side. (c): Angle and distance for the left side.

2. Image for left DDH, Figure (14).

Right side result :

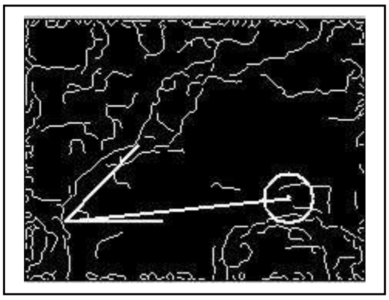
a. Canny = 1
b. Center (X,Y) = (50,95)
c. Center Intensity =151
d. Diameter =3.9206mm
e. Angle =28.8557 º
f. Distance =5.4487mm

Left side result :

a. Canny = 1
b. Center (X,Y) = (172,117)
c. Center Intensity = 145
d. Diameter =1.5760mm
e. Angle =46.1691 º
f. Distance =27.7895mm

(a)

(b)



(c)

Figure (14): (a): Image for left DDH. (b): Angle and distance for the right side. (c): Angle and distance for the left side.

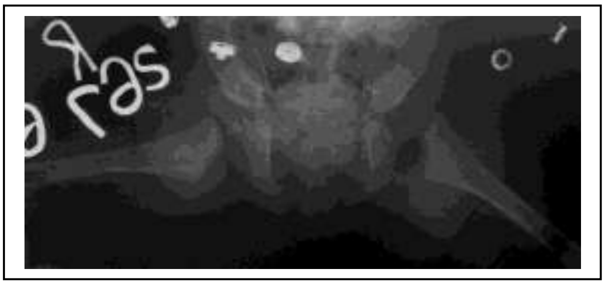
3. Image for left DDH, Figure (15).

Right side result :

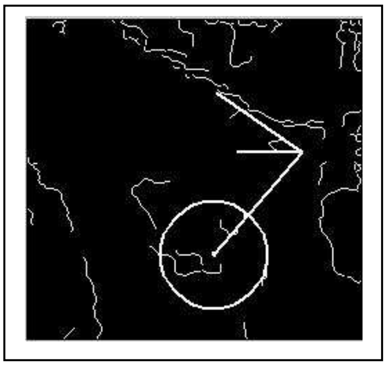
a. Canny =4
b. Center (X,Y) = (136,171)
c. Center Intensity = 107
d. Diameter = 3.8543mm
e. Angle =34.7432º
f. Distance = 4.0706mm

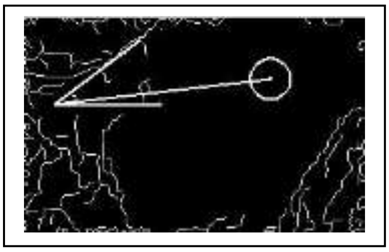
Left side result :

a. Canny =2
b. Center (X,Y) = (208,52)
c. Center Intensity = 72
d. Diameter =1.6945mm
e. Angle =37.5065º
f. Distance =31.2583mm



(a)





(c)

(b)

Figure (15): (a): Image for left DDH. (b): Angle and distance for the right side. (c): Angle and distance for the left side.

4. Image for left DDH, Figure (16).

Right side result :

a. Canny =2
b. Center (X,Y) = (135,204)
c. Center Intensity = 82
d. Diameter = 4.6739mm
e. Angle =30.5560º
f. Distance = 23.7709mm

Left side result :

a. Canny = 3
b. Center (X,Y) = (428,173)
c. Center Intensity = 53
d. Diameter =1.8114mm
e. Angle =40.3836 º
f. Distance =104.9368

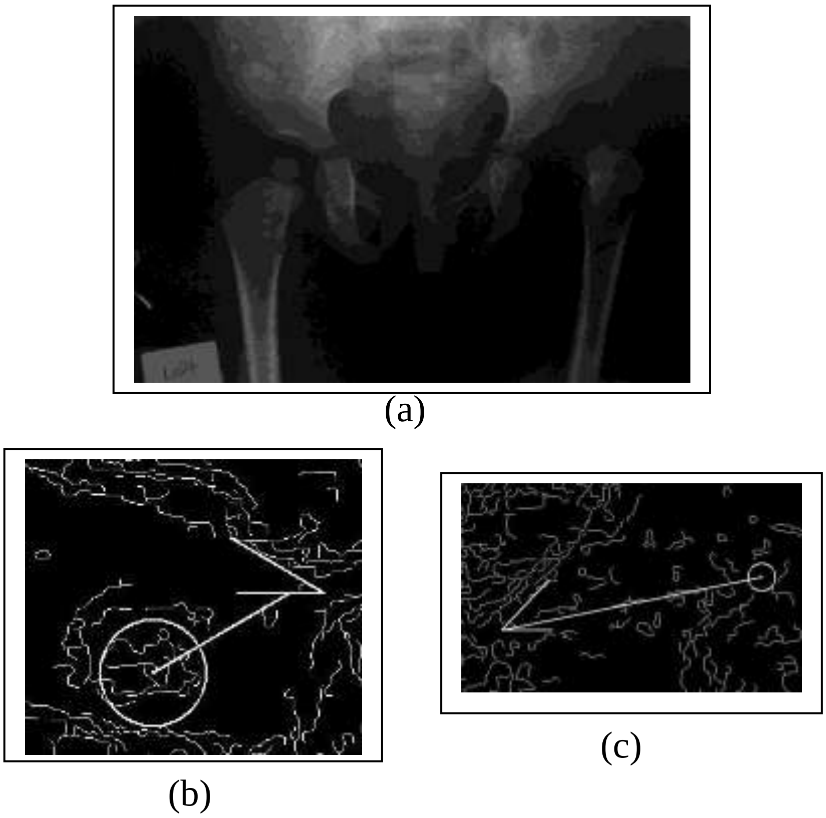


Figure (16): (a): Image for left DDH. (b): Angle and distance for the right side. (c): Angle and distance for the left side.

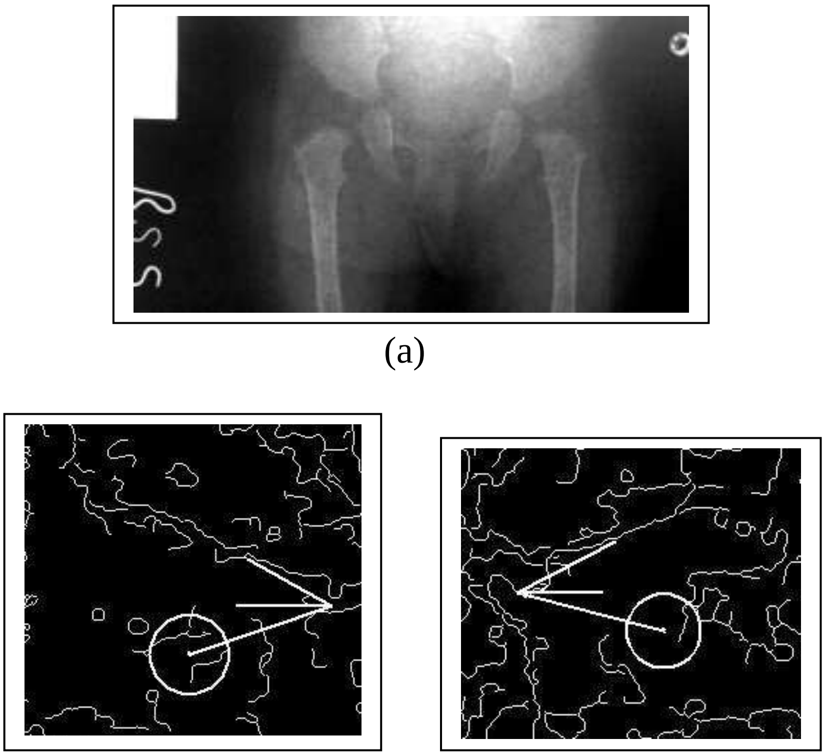
5. Image for Normal case, Figure (17).

Right side result :

a. Canny =3
b. Center (X,Y) = (122,179)
c. Center Intensity = 108
d. Diameter = 2.8617mm
e. Angle =29.1343º
f. Distance = 10.5646mm

Left side result :

a. Canny =3
b. Center (X,Y) = (157,142)
c. Center Intensity = 113
d. Diameter = 2.5084
e. Angle =27.5820 º
f. Distance =13.2109mm



(a)

(b) (c)

Figure (17): (a): Image for normal case. (b): Angle and distance for the right side. (c): Angle and distance for the left side.

Conclusions

1. We used Mask Technique to capture the desired area. This technique gives high accuracy and reduces the execution time required to detect these features, and can be used to detect other problems.
2. Diagnosis is done in two phases:
   - Search on the center of the head of femur and calculate it's diameter.
   - Measure the angle of acetabulum bone and measure the distance from head of femur to acetabulum bone.
3. Finds new features Diameter, center and angle detection which can be used for any problem which has a shape like circle and triangle.
4. Do not need this system for large memory, but a small memory to store the picture before diagnosis and another to store the small cropped parts.
5. This diagnosis system is very simple and do not need any steps or rotations to learn like artificial techniques, and this helps to reduce the execution time required to detect these features.
6. This diagnosis system helps to diagnose one of the DDH effects on the upper end of the femur bone for child which help the doctor to observe one of the affections of DDH, and to detect the angle of acetabulum which help the doctor to diagnoses the degree of DDH.
7. In the future this system needs a library with normal measurements to compare with it, like the normal size of head of femur and angle of acetabulum for each child age

References

1. Al Neamy, J.S.M. 2006, "Brain Tumors Image Diagnosis Using Hybrid Intelligency Techniques", Ph.D Thesis, Mosul University.
2. Barnett CH; Davies DV; Macconail MA. The hip joint *In:* William and Warnick (eds). Gray's anatomy. 36th ed. Chirchill Livingstone, London. UK. 1980; 477-482.
3. Beaty JH. Congenital and developmental anomalies of the hip and pelvis. *In:* Canale ST, Cambell's Operative Surgery. 9th ed. Mosby. St Louis, USA 1998; 1021-1022
4. Demuth, A. and Beala, M., 1998, "Neural network tool box", The Works, version 3
5. Gonzalez, R.C. and Woods, R.E., 2002, "Digital image processing", Prentice Hall, Second Edition.
6. "MATAB The Language of Technical Computing", Version 7.0.0.19920 (R14) May 06 , 2004.
7. Nidal H., Mafaz M. and Shahla, H., 2007, " Using Mask Technique and Center Detection for Congenital Dislocation of the Hip (CDH) diagnosis", Al-Rafiden Journal of Computer Sciences and Mathematics, version (1) ,Vol.(4) ,2007.
8. Tinku Acharya and Ajoy K. Ray (2005), "Image Processing Principles and Applications", Published by John Wiley & Sons,   Inc., Hoboken, New Jersey. Published simultaneously in Canada.

تطوير تقنات البرمجة الحاسوبية لقياس درجة الخلع الولادي لدى الاطفال

مفاز محسن خليل

(تاريخ الاستلام: / /٢٠٠٧ ، تاريخ القبول: / / ٢٠٠٧)

الملخص

يهدف هذا البحث إستخدام الأسلوب المقنع وتحديد المركز لتشخيص الخلع الولادي الذي يقوم بحساب المركز والقطر لكرة رأس عظم الفخذ لتشخيص إحدى تأثيرات الخلع الولادي على عظم الحوض[7] .

تستخدم هذه الدراسة الأسلوب المقنع وتحديد المركز [7]لحساب مقدار زاوية ميلان تجويف عظم الحوض أي المكان الذي تستقر فيه كرة رأس عظم الفخذ والمسافة ما بين هذه الكرة و ذلك التجويف. تعطي هاتان المعلومتان للطبيب معلومات قيمة تساعد في تشخيص الخلع الولادي ودرجته.

صممنا خوارزمية لانجاز الخطوات التالية:

١. التحري في تفاصيل صورة الأشعة وقطع الأجزاء الضرورية (تجويف عظم الحوض و كرة رأس عظم الفخذ) للجهة المرغوبة (يمين أو يسار) بدلا من إستخدام الصورة كاملةَ.
٢. تحسين درجة وضوح الأجزاء المقطوعة باستخدام المد الخطي للتباين، المرشح الوسطي وكشف الحافات لكاني.
٣. البحث عن مركز كرة رأس عظم الفخذ وحساب قطرها.
٤. قياس زاوية تجويف عظم الحوض والمسافة ما بين كرة رأس عظم الفخذ والتجويف.

وأخيرا لقد تم إستخلاص الصفات التالية (مركز كرة رأس عظم الفخذ ، قيمة كثافة المركز، قطر كرة رأس عظم الفخذ، زاوية تجويف عظم الحوض، والمسافة من كرة رأس عظم الفخذ إلى مكانه الأصلي في تجويف عظم الحوض). تم تطبيق هذا النظام حاسوبيا باستخدام اللغة البرمجية Matlab 7.0.