

Fundamental Study On Proposed Cad Based Paediatric Hydronephrosis Classification Model Framework By Enhanced Seed Pixel Region Growing Segmentation And Logistic Regression Classifier Algorithm

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Abstract: Paediatric Hydronephrosis (HN) is a disease occurs in urinary tract by dilation of kidney (i.e., “water inside the kidney and swollen”) in children’s. Hydronephrosis can be caused by conditions that the child is born with congenital or by conditions that develop after birth. The main challenge of 2D Ultrasound image of hydronephrosis dataset have more noise, and hard to predict the renal dilation in the image through manual process during early stage. In literature, a large number of computer aided diagnostic (CAD) systems using different image modalities, such as ultrasound (US), magnetic resonance imaging (MRI), computed tomography (CT), and radionuclide imaging, have been proposed for early detection of kidney diseases but not for hydronephrosis. The main objective of the study is to design new algorithm and develop a computer aided diagnosis framework for early detection of hydronephrosis in children’s to avoid the risk level. The proposed work in this paper is to design a complete framework and new algorithm for segmentation and classification of renal structures which consist of image acquisition, image enhancement, segmentation, feature extraction and classification, whereas in initial stage, ultrasound of kidney image is diagnosed and identify the distortion of renal parenchyma structure caused by the obstruction of urinary tract and abnormality are studied. From the automatic segmentation (i.e. proposed seed pixel region growing method) of renal parenchyma and collecting system in 2D ultrasound images, an optimal set of morphological descriptors (i.e feature extraction) of the kidney are automatically extracted and used as inputs features of a machine learning algorithm. The classifier (i.e proposed logic regression classifier) is able to predict the degree of hydronephrosis of the renal unit, identifying with maximum sensitivity the severe cases that require immediate medical attention, while maximizing the number of noncritical cases where diuretic renography can be avoided. The enhanced seed pixel region growing segmentation and logic regression classification helps to diagnose the presence of hydronephrosis (HN), which leads to an early detection of swollen kidney in children’s and improve the accuracy of risk predication rate.

INTRODUCTION

Hydronephrosis is the disease which will accumulate the urine in the kidney’s drainage system (—the calyces and renal pelvis) and makes the kidney to swell [1] [2].The reason of occurrence is due to obstacle in the normal urine flow (Urinary tract) or backflow of urine from the urinary bladder. Swelling normally affects one kidney; sometimes it can affect both kidneys. As per the statistics in US, hydronephrosis disease affects one out of every 100 babies. The hydronephrosis disease is not a primary; it is a secondary disease which results due to other principal diseases. Below figure 1 illustrates images are the normal urinary tract and infected urinary tract.



Figure 1 (a) Normal Urinary Tract b) Ureter Obstruction
[Source: Children HealthCare of Atlanta]

The diagnosis of urinary tract can be observed through various imaging modalities [3] [4] which give a detailed report on anatomy and functionalities. One of the popular methods of diagnostic imaging is Renal Ultrasound Imaging (RU) where the early screening can be performed to diagnosis the disease. The process is a non-invasive procedure, where it clearly shows the size and shape of the kidney, so it helps the urologist to diagnose the disease in early stages. The main challenge of the approach is missing of swell in early stages leads to the complication in later stages. Therefore to overcome the challenges Computer Aided Detection (CAD) systems are proposed through enhanced machine learning approaches.

The CAD system proposed in this study is a very broad area that integrates the image processing and statistics to form a computerized decision making system. The proposed approaches will assist the radiologist, urologist in their decision making process and act as a second reader for detection, classification, quantification, risk assessment and evaluation, which is illustrated in figure 1.

CAD systems are in infant stage, where it is a combination of artificial intelligence and computer vision processing in the



specialized field of medical imaging. The different imaging modalities are used in CAD system for detection and classification. In fact, CAD systems have been one of the major research areas in medical diagnostic imaging and machine learning [2]. In current research works of machine learning paradigms, most robust and reliable classifier algorithms are applied in acquired medical images for detection of various diseases. The proposed CAD systems not only process the images, it analyze the image dataset, it determines the category of images belongs to which class (healthy and un-healthy) and compare it to pathology reports for automatic diagnosis. The working components in general CAD systems comprised of four modules: Pre-processing, where it enhances the image quality by filtering the noise, Segmentation, where it hunts for the region of interest and segment the abnormal object or structure, Feature extraction, selective features / properties are extracted from the segmented object, Finally classification is performed to identify the segmented object is accurate or not. The general CAD architecture is burrowed in our study for diagnosing the obstruction in urinary tract by seed pixel region growing and logistic regression classifier algorithm.

The main objective of the study is to design a new algorithm and develop a computer aided diagnosis framework for early detection of hydronephrosis in children's to avoid the risk level. In Section 2 explains the problem statement, Research objectives are explained in Section 3. Section 4 explains the research background on pediatric hydronephrosis and machine learning approaches. Section 5 explains the existing works of image enhancement, segmentation and classification. Section 6 explains the proposed methodology of seed pixel region growing and logic regression classifier framework. Section 7 provides the expected outputs as the proposed work is in fundamental stage and its concluded.

PROBLEM STATEMENT

The CAD system for ultrasound images have highly created an attention of diagnosing the disease earlier with accurate and reliable results, but for disease such as hydronephrosis diagnosed early by ultrasound images have challenges in Ultra Sound (US) 2D image analysis. The problem statements for the proposed research study in early investigation are categorized into:

- Ultrasound Image of hydronephrosis have challenges from low signal to noise ratio, signal attenuation and drop out and missing boundaries, and difficult to evaluate the organs.

- Manual localization and segmentation is a tedious process, segmentation is challenged due to undefined shape, blurred boundaries, heterogeneous structure of different shape and intensity inside the kidney i.e renal parenchyma structure for the young children's, it's hard to detect and confuse the experienced radiologist while carry out the manual observation. More experience and training is required to interpret the ultrasound images. Even human experts differ in the interpretation of ultrasound images. The available segmentation and classification algorithms are general techniques and fail to detect the real dilation from ultrasound image for hydronephrosis detection. The manual methods of segmentation needs high attention of ultra- sonographer and also suffer from poor accuracy and time consuming.
- In classification of hydronephrosis disease, there were no accurate parameterization proposed in previous literature to improve the accuracy and guarantee the optimal performance and robustness.

FRAMED RESEARCH HYPOTHESIS AND QUESTIONS

The underlying research hypothesis framed for the fundamental study is:

HO: Hydronephrosis can be objectively quantified using latest image analysis approaches of Ultrasound images, but there is a correlation between the degree of hydronephrosis in early stages and the severity of the obstruction as measured by image modality (diuretic renography) method.

Research Questions:

The following research questions are focused to conduct the study based on framed hypothesis:

- ✓ How the speckle noise is reduced in the 2D ultrasound kidney images, what design parameters are considered for the speckle reduction and optimize the image registration?
- ✓ How region of interest is determined to extract the renal structure for segmentation?
- ✓ For improving the classifiers, how resulting logistic regression classifiers are faithful with respect to the data i.e., the dependencies and independence of the data are represented correctly?



REVIEW

For this proposed research, very limited machine learning approaches were proposed by different authors for hydronephrosis diseases and not effective with accuracy results. There are several existing approaches for other kidney diseases were made to detect the suspicious region in ultrasonic images. Segmentation of the abdomen, in particular, is often a challenging task due to the considerable overlap of soft tissues by [5]. Since intensity based methods have met with limited success for abdominal segmentation, texture segmentation, which makes use of statistical textures analysis to label regions based on their different textures, has attracted our attention. In this approach, low-level features based on texture information, that is expected to be homogenous and consistent across multiple slices for the same organ, are mostly used to perform automatic image analysis in the medical imaging field investigated by [6]. Region based methods focus attention on an important aspect of the segmentation process missed with point based techniques. There a pixel is classified as an object pixel judging solely on its gray value independently of the context. This meant that isolated points or small areas could be classified as object pixels, disregarding the fact that an important characteristic of an object is its connectivity. If we use not the original image but a feature image for the segmentation process, the features represent not a single pixel but a small neighborhood, depending on the mask sizes of the operators used. At the edges of the objects, however, where the mask includes pixels from the object and the background, any feature that could be useful cannot be computed. The correct procedure would be to limit the mask size at the edge to points of either the object or the background [7]. For kidney tumor segmentation, the region growing method was applied from the center of the selected seed region as the starting point. Generally, the region growing method performed the homogeneous test from the start pixel to the neighbor pixel using gray level, texture, and color as acceptance criteria, and included or excluded the neighbor pixel according to the homogeneous test result until termination condition was satisfied [6] [7][8]. Computer Aided Diagnosis (CAD) for classification of focal liver tumors in sonography requires segmentation as a preprocessing step for successive texture analyses of the tumors [7] [8] [9][10] [11] [12]]. Therefore only very few researches have directly examined the hydronephrosis images in 2D and 3D ultrasound images and applied machine learning approaches, computation of hydronephrosis index (HI) was not accurate and classification results were lagging compare to manual

methods. In this study, automated segmentation and classification framework performs the function, without the need for an interaction from the user to diagnosis the kidney structure and extract the feature for classifying the level of disease without invasive functional imaging [13][14]. As per the review, machine learning techniques are widely used in medical image datasets, but for hydronephrosis datasets, it is very limited and research study is conceptual stage. There were no specific machine learning approaches are applied to detect the pediatric hydronephrosis disease and predict the risk levels based on manual grading HN grading system.

RESEARCH OBJECTIVE

Among all type of imaging modalities, ultrasound images play a crucial role, because they can be produced at video rate and therefore allow a dynamic analysis of moving structures. Apart from that, the acquisition of these images is noninvasive, cheap, and does not require ionizing radiations compared to other medical imaging techniques. The research challenge of segmentation of anatomical structures in our proposed ultrasound imagery is a difficult task due to speckle noise and artifacts which are inherent in these images. Speckles in an ultrasound image were treated as noise and our proposed algorithm reduces the noise in the image. Speckle gives ultrasound images their characteristic granular appearance. It inherently exists in coherent imaging, including ultrasound imaging. Due to the relatively low quality of clinical ultrasound images, a good ultrasound image segmentation and classification method needs to make use of all task specific constraints or priors.

The main objective of the proposed research is fundamental frameworks that make contributions to a CAD system which can provide a “second opinion” to radiologists/urologist on a routine clinical basis. The proposed framework, when it leads to new algorithm design and pilot prototype development in this project, which can helps in 1)Improving the quality of diagnosis 2) Increasing therapy success by early detection of Disease 3)Avoiding unnecessary biopsies 4)Reducing radiotherapist interpretation time 5)Improves the accuracy and reliability of detection.

The objectives of the proposed research are as follows:

1. Study the state of the arts of CAD system for hydronephrosis and other kidney disease
2. Design an enhanced filtering algorithm to reduce the speckle noise in ultrasound kidney image. Therefore proposed image enhancement is based on the process of

digitization and preprocessing the kidney images to eliminate speckle noise for better visual quality.

3. Design an enhanced seed pixel region growing segmentation algorithm and mathematical model for extracting the morphological/geometrical features from the extract renal parenchyma structures
4. Design and implement a logistic regression model classifier approach to classify the level of hydronephrosis thickness (HI) from mild to moderate to advance based on morphological feature descriptors.
5. Implement, validate and integrate a specific computer based model for hydronephrosis disease and validate the performance of the prototype based on accuracy, correctness and sensitivity.

The complete prototype is run for validation. It is a physical experimental of the prototype. Tasks include observation from urologist, comparing from the result of the segmentation of kidney structure with extracted features and classification with the diagnosis given by the clinical biopsies. At the end we will have percentage of accuracy of the system in all aspect of renal dilation observation the percentage of number of false positive detections, percentage of missing data and uncertainties, percentage of confidence of the classifiers respect to the data.

MATERIALS AND METHODS

The proposed methodology in fundamental study has five distinct steps to predict the risk level of hydronephrosis: preprocessing, seed pixel selection, region growing region merging of pre and post segmentation, feature extraction and logic regression classifier framework as shown in figure 2.

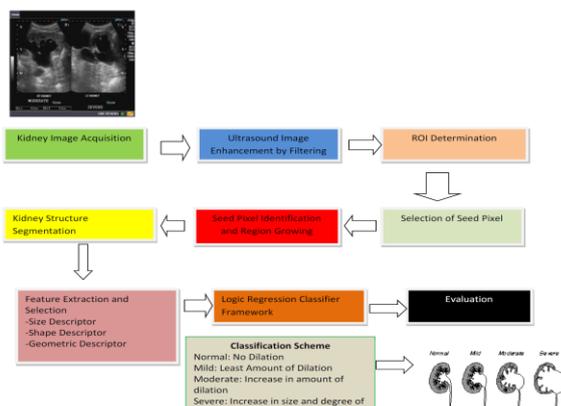


Figure 2 illustrates the Proposed Framework Model of CAD based Hydronephrosis

Initially the 2D ultrasonic image of kidney is acquired, and preprocess by filtering techniques, and from the automatic seed pixel region growing segmentation of renal parenchyma and collecting system in 2D US images, an optimal set of morphological descriptors of the kidney are automatically extracted and used as inputs features of a machine learning algorithm. Logic Regression classifier is able to predict the degree of hydronephrosis of the renal unit, identifying with maximum sensitivity the severe cases that requires immediate medical attention.

Filtering Approach: Filters are used to de-noise signals and images. In 2D Ultrasound images, Ant bee Colony (ABC) optimization filtering technique is proposed to reduce the noise speculation. The ABC algorithm is a new, simple and robust algorithm, based on swarm intelligence. This algorithm was first introduced by the author Karaboga. It can easily be used for solving some optimization problems and finding optimal or near optimal solutions to numerical and discrete problems. The proposed filtering algorithm was designed to obtain the general filter coefficient for speckle noise reduction. The SNR, PSNR and MSE values were measured as performance parameters [12].

Seed Pixel Region Growing: The framework extracts texture features for each pixel in the region of Interest. The proposed system uses the texture features, i.e. texture features are computed for pixels in each slice of kidney ultrasound image. This automatic region growing algorithm, takes a set of seeds as input along with the image [12]. The kidney region to be segmented is marked by the seeds. By comparing all unallocated neighboring pixels to the regions iteratively grows the regions. The similarity measures used in this model are the difference between a pixel's intensity value, region's texture and local threshold. This technique is presented as, first preparation of lookup table of local statistics of all pixels to be used for initial region growing procedure, second grouping of pixels satisfying a specify homogeneity criteria and produce the homogeneous region, and finally merging the neighboring regions, which have similar intensity values with the tolerance level. The pixel with the minimum difference measured this way is allocated to the respective region. This process is repeated until all pixels are allocated to a region. The additional input to the seeded region growing process is it requires seeds. The segmentation process results are dependent on the choice of seeds. Noise in the image can cause the seeds to be poorly placed.



Feature Extraction: The segmentation slice of the kidney and its collecting system, are processed by means of image analysis techniques to automatically extract a set of morphological parameters of the kidney. These quantitative shape descriptors can be intuitively grouped in the following three categories. Morphological features were calculated based on first order statistics, spatial graylevel dependence matrices, and spatial frequency content. We have proposed to construct two sets of features: statistical and spatial frequency based. To determine the optimal subset of features, a third set was concocted by merging the two sets into a combined set of 14 features. As the features have different physical units, and thus substantial difference in variances, it was necessary to normalize them prior to feature selection. Therefore, we scaled each feature to have zero mean and unit variance. The normalized features were used in all subsequent analysis. Apart from that, the potential utility of such morphological descriptors for assessing hydronephrosis has been stressed by several authors, attempting to analyze ultrasound imaging of hydronephrosis in more objective ways. The “hydronephrosis index” defined by Saphiro et al. [15] as the ratio between the area of the renal parenchyma and the total area of the kidney, has been shown for correlation.

Logic Regression Classifier: Logistic regression (LOG) is a binary classifier that performs probability estimation using logistic formula. We use logistic regression analysis as the classification model and correlation variance method to start training for detecting renal dilation based on feature selection. The logistic regression model is designed to classify the risk predication levels.

Evaluation Module: The assessment of renal dilation classification performance is performed using receiver operating characteristic (ROC) analysis. In this study, to determine the efficacy of each feature subset, its performance was estimated via ROC and FROC analysis. Receiver operating characteristic (ROC) curve analysis is used to identify the operating points with the highest accuracy, sensitivity and specificity of each classifier. The ultimate objective is to identify those probability thresholds that maximize the sensitivity of detecting severe cases of hydronephrosis; that is, no case with a washout time above the defined threshold is misclassified. Thus, diuretic renography could be safely avoided in those cases classified as nonsevere, reducing the number of unnecessary ionizing imaging studies.

The current proposed system will be implemented in MATLAB. The urinary tract (hydronephrosis) images will be collected for early experimental work with proper ethical clearance from the hospital. Once the prototype is completed, more live datasets will be gathered from hospital to conduct real time experiment. First the training sets of data are inserted to indexed database and make it available for the experimental task. Radiologist will verify and validate of the findings. Findings will be collected and parameter such as percentage of hit, precision and recall are computed. The fundamental studies based on prototype development will lead in later stages to new outputs. The expected outputs from the initial study are:

- New or improved algorithms

By adding Enhanced Seed Pixel Region Growing and Morphological Feature Extraction, Logic Regression Classification, new improved algorithm is developed for pediatric hydronephrosis to predict the risk levels.

- Prototype Development

The prototype will act as second reader for radiologist for comparing the results of the hydronephrosis classification with the diagnosis given by the clinical biopsies. Percentage of accuracy is increased and number of false positive detections is decreased

The proposed work with scientific evidence through clinical trials will show that ultrasonic screening reduces the mortality and morbidity associated with pediatric hydronephrosis. Once the framework is developed on fundamental basis, it will create a strategic partnership between global health care industries and research universities. Development of this product will enhance the health care industry standards with new innovations. It can help to create new platforms in hospitals, bioinformatics, biomarkers, clinical research and medical equipment manufacturers.

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EXPECTED OUTPUTS AND CONCLUSION



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