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4D Image Analysis and Diagnosis of Kidney Disease Using DCE-MRI Images

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Abstract

Because of noninvasive nature, medical imaging is easy to perform though it is extravagant. For furnishing superior anatomy and decisiveness, different characteristics have been extrapolated from intake image. Earlier the processing steps like registration, segmentation are separately applied for extraction of sequential proprieties of DCE-MRI images of kidney. For simultaneous registration and segmentation of the kidney, a 4D model is described. In the conscript of kidney abnormal functioning and disease detection, the glomerular filtration rate (GFR) is a significant factor. Dynamic contrast enhancement magnetic resonance imaging (DCE-MRI) is the imaging proficiency, used for calibrating different parameters homologous to suffuse, capillary leakage, and convey rate in tissues of various organs and diseases detection. The described technique's approach permits us to automatically accomplishing a statistical analysis of various parameters from alive cells. Conclusion of findings is accomplished by average gray level intensity inside the kidney region.

Keywords: *DCE-MRI, Kidney, Registration, Segmentation, Renal Function, GFR, Spatial mapping, CKD.*

1. Introduction

Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCE-MRI) is used by radiologist for diagnosis of antithetic contaminations. For a little while, pronouncement is concluded through biopsy, which may expedite bleeding and infections in the humanitarian. Teensy irk biopsies may effectuate overestimation or underestimation of the excess of inflammation. In DCE-MRI, GD-DTPA is a contrast chemical agent injected into the patient's bloodstream to perfuse inside ilk, precipitated in recreation of flush, to catalyze a discrepancy image of organ. The working facts and MRI gives analyzed data, habituated to catch out affections.

DCE-MRI of the kidney has advantages: i) Radiation exposure is not required ii) Three dimensional acquisitions are used iii) spatial resolution is superior.[18] Accompanied by difficulties like: i) low spatial resolution due to fast scanning, ii) selection of proper registration process, iii) choosing correct segmentation process. In the ilk debilitation, GFR is the foremost parameter. GFR is measured from the blood pool in the glomerular capillaries of the volume of filtered fluid per unit time. If the value of GFR is low, then there are chances of diseases and dysfunction of the breed. [20]

In the existing system, there is no focus on the voxel based GFR measurement from DCE-MRI acquisitions. In 3D model optimization problem is observed. Registration and segmentation move are not associate together. This model did not contribute for diagnosis. In the proposed system, these problems can be overcome by using a 4D model rather than 3D model. 4D model fragment the ascription by catering registration and segmentation. In 4D model 4 steps convoluted are

(i) Registration.
(ii) Segmentation.
(iii) Compartment modeling.
(iv) Combined of registration and segmentation.

1.1 Risk factors diagnosis and classification:

Kidney affliction appertains to any renal pathology that has implied to antecedent deduction in renal operative interact. This is most imposing associate with a reduction in GFR but other imperial functions may be mislaid within this to be found. [22]

Diabetic Mellitus: Diabetic nephropathy is a renal complexity of diabetic mellitus. The association of diabetic with inopportune bear of

chronic kidney disease (CKD) is more excruciating to substantiate. In one cross sectional study diabetes was relative imminence aggrandizing with the despotic of CKD.
Hypertension: It is a hazard aspect of CKD.

1.2 Detecting Kidney Damage:

Kidney damage may be detected directly or indirectly by using imaging or hostopathelogical examination of renal biopsy direct evidences found out. Imaging types used are computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and isotope scanning may detect number of structural monstrosity. The structural abnormalities include polycystic kidney disease, reflux nephropathy, chronic pyelenephritis and renovascular disease. From urinalysis, indirect evidence may be inferred for kidney damage. [23].

2. Literature Review

Literature survey is able to critically summarize the current technology in the area of nephrology for any potency and debilitation in precedent work. Identify the technique to eliminate the implicit wimpiness, whilst bringing to the fore the potential strengths.

a) Reviews on kidney tests and diagnosis techniques: Blood and urine tests can be performed to check for the kidney function. In order to diagnose and confirm disorders related to kidney blood vessels, tolerant can endure kidney biopsy proceeding. Imaging tests are performed to get useful information about kidney structures. [22] **Blood tests:** commonly used tests are blood urea nitrogen and serum creatinine from the blood samples. The concentration determination of these two substances is not sensitive enough as the concentration will not exceed the normal reference ranges until there is loss of more than 75% of kidney function. **Urine tests:** The degree of kidney impairment can be assessed by measuring the GFR, and information on the cause of the disease can be achieved by urine test. **Imaging tests:** to get useful information regarding the kidney structures using different imaging modalities.

Fredrik Maes et al [1] propose images registration using maximization of mutual information (MMI) for CT and MRI images. The steps used are non-rigid image matching, rectification, shape normalization, motion estimation, tissue deformation correction all are the area to be explored. Macros Martin-Fernandez et al [2] developed an approach for contour detection of human kidneys from ultrasound images using Markov random fields and active contours. It is a probabilistic Bayesian method. Segmentation of a vivo kidney out of volumetric series of 2D echo graphical slices. But quality of solution is a problem with ultrasound imaging. Ali Gholipour et al [3] provided classification of the image registration techniques for CT and MRI images for proper selection based on resolution. Asem M. Ali et al [4] explore the idea on graph cuts frameworks by using segmentation with proper shape constraints of the kidney. Provide results better than clinical results but with manual inputs. Giele et al [6] ameliorated the antecedent techniques by appertaining erosion to the mask image to acquire a contour via a second deduction stage. Several rings were obtained, which formed the basics of the segmentation of the cortex from the medulla structures. Boykov et al [7] used graph cuts to get a across-the-board optimal intention extraction approach for dynamic N-data sets for minimized cost function. Although the results appeared auspicious, manual interaction was still challenge. Priester et al [5] abated the average of pre-contrast images by using generated threshold from the average of early-enhancement images, and black-and-white kidney mask. This mask image is corroded and the kidney contour is acquired with help of manual interactions. Sun et al [8] introduced numerous computerized artifices for kidney segmentation and registration. Aly A. Farag et al [9] offered an efficacious come up for the shape based segmentation problem using level sets. It is based on dissimilarity scales by using a dissimilarity measure approximated by a smeared version of the maximum function using DCE-MRI images. Frank G. Zollner [10] et al explored idea on image analysis methods in the assessment of human kidney perfusion based on 3D DCE-MRI data. Found the K-means clustering is a suitable approach for time course analysis of renal perfusion when proper motion correction is performed as a preprocessing step, but it deals with the processing of observed

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signal time intensity courses only. Tilo W. Eichler et al [11] explore the automated cell segmentation represents a robust and powerful tool for the statistical analysis of various cell parameters. Toufik Sari [12] provided several binarization techniques with feature extraction. Nick method is the best binarizaton method among all methods. Volker Daum et al [13] proposed work on segmentation of kidneys using a new active shape model generation techniques based on non-rigid image registration with curvature-based image registration gives an attractive alternative to minimum description length (MDL) based techniques. Davies et al [14] proposed a description of an automatic method for the construction of optimal 3D statistical shape models. V Rajamani et al [15] worked on comparison of local binary pattern variants for ultrasound kidney image retrieval. The efficiency of the system is measured using recall and precision parameter. S. Manikandan [16] analyzed various features of an ultrasound kidney images using gray level co-occurrence matrices. Jeff L. Zhang et al [17] characterizes the renal functions presents in MRI of the kidney. Limitations of the tools are robust image registration and segmentation, broad area of tools for MRI interpretation of Blood Oxygen Level Dependent (BOLD) measurement, also the challenges with respiratory and bulk motion of tissues are critical to measure in function renal MRI. Junchi Tokuda et al [18] worked on non-rigid motion segmentation with motion correction techniques on pixel wise pharmacokinetic analysis of free breathing pulmonary DCE-MRI. It is for therapy response only. Louisa Bokacheva et al [19] estimate on GFR from MR Renography and tracer kinetic models. 4D or 5D model can provide RPF but with high SNR is the limitation of this system. A. M. Khan et al [20] provided various segmentation methods. It is hard to obtain single answer for segmentation of given images as the interpretation varies from individual approaches. Hodneland et al [21] introduced the idea of combination of registration and segmentation which is applicable to the 4D DCE-MRI of moving human kidney. The limitations to this system are GFR measurement and diagnosis of renal diseases. Yetzi et al enhanced his work on segmentation and registration in active contours of 2D images. For non-affine registration this method is not suited. From survey it is found that various imaging modalities, segmentation and registration techniques are proposed. Features selection is a critical issue and need to resolve. There is need to combine the segmentation and registration process and identify the proper features for automatic kidney disease diagnosis using suitable imaging modality. With this intention we have proposed a new MRI renography approach for diagnosis of various renal diseases and GFR value measurement and optimization of image. Proposed system is an integral model with the combination of registration and segmentation.

3. Proposed System

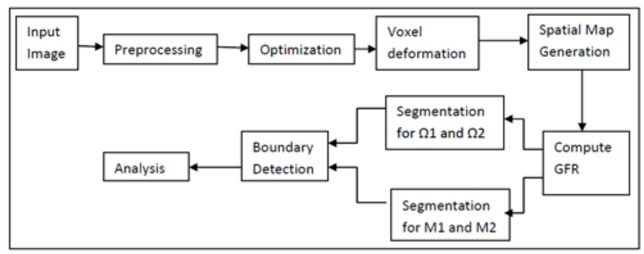

Fig. 1 General Block Diagram of the Proposed System

In the existing system there is a huge work carried out on 2D and 3D model which contains registration, segmentation and compartment modeling but it consists of optimization problem. Manual segmentation included most of the system so there is problem of handshaking errors. Image registration and segmentation provided are not robust to the noise. Also GFR is not computed previously which is an important parameter for filtration rate calculation. Acute rejection and normal patients classification is not possible. There is no approach toward diagnosis of renal diseases in the past.

In the proposed system, the optimization problem can be overcome. Handshaking errors can be removed by automatic segmentation. It is the combination of simultaneous registration and segmentation, also calculates the GFR value by using voxel deformations. Also boundary area is separated by using the spatial mapping and segmentation on the area of the image.

Set of some standard rules can be defined for the diagnosis of various renal diseases of the kidney. In 4D model, proposed system extracts the features by combining registration and segmentation.

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i) Registration: Procedures of registration classification depend on the registration paradigm. Features are either extrinsic or intrinsic. Extrinsic method is related to external objects or markers introduced in the image space. Intrinsic method can be point based or surface based or voxel based. Voxel based registration method optimize a functional measuring the similarity of all geometrically corresponding voxel pairs for some features.[1] Anatomical objects extracted from 3D medical images are aligned using affine transformations to remove the global size differences. The affine transform T of point $p = (p_1,\ldots,p_d)' \in R^d$ to $q = (q_1,\ldots,q_d)'$ is given by

$$q = Rp + c \qquad (1)$$

Where the matrix R corresponds to rotation, scaling and shear and c corresponds to translation.

ii) Segmentation: approach behind the segmentation is to simplify image which is more meaningful and easier for analysis purpose. The system gets contours of extracted image or a set of segments which covers the whole area of an image from this segmentation procedure. Image segmentation is the fundamental step to analyze images and extract data from them. Region growing method has better performance for DCE-MRI images. [9]

Algorithm for region growing method

Let R represent the entire image region and let p be any predicate.
If P(R) = False
Divide image into quadrants
If p is possible for any sub quadrant
Subdivide that quadrant into sub quadrant.
Stop dividing when P is true.
Merge the regions Rj & Rk (j ≠ k; j = 1,2,3,…..,n, k = 1,2,3,….,n)
if P (Rj Є Rk) = = true

iii) Compartment Modeling: There are one or two compartment models formed in the system which has parts of tissues, as the contrast agent gets exchanged. For DCE-MRI images, these models are more simplistic. If models have more than two compartments, redundancy issue gets developed. Because of these redundancy issues system cannot find model parameters which are important. If the model is more complex there is regression problem arises. However, a spatial elastic approach can be used which provides number of compartments for each voxel so that model complexity is not fixed. As we use a spatial elastic approach, the system gets a sparse set of basic functions for each voxel, so that the rate gets constant in each compartment. For simulated images this method is used and it can be applied to vivo datasets also. [21]

iv) Combined Registration and Segmentation: For combination of registration and segmentation, use elasticity regularizes and distance measure. In between template and reference image there is a smooth deformation. 3D images are formed by using sequentially parallel 2D images, in which a smallest element present has a cubic volume is called a voxel. 3D images have limited spatial resolution, minor artifacts and gray scale, to avoid its effect before image viewing, image filtering should be done. Patients' anatomy and physiology are given by 3D images. 4D images are formed by using temporal series of 3D images. 4D images represent patient's motion over time. Patient's motion can be faster or slower. Faster motion related with speed which causes blurring artifacts and slower motion may not be affected on the image quality.

Figure 1 shows the general approach of the proposed system. In the system DCT-MRI image is an input which is first preprocessed. Then carry out optimization to overcome Optimization problem. Voxel deformation is done after the optimization of the image for GFR calculation. Spatial mapping is required for boundary detection to differentiate between kidney and other than kidney area for accurate segmentation of kidney wall regions. System will compute the GFR from Voxel deformation's RMSE measurement for kidney region. Segmentation is required for kidney wall and remaining area of the image for both kidneys separately to avid errors. Boundary of kidney wall is detected by using canny edge detector. After that carry out analysis by using some set of standard rules suggested by radiologist, which is required for diagnosis of the renal diseases.

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4. Conclusions

(a) (b) (c) (d)

Figure 2: (a) Original Image after Preprocessing (b) After Gaussian Filtering (c) Result of Thresholding (d) Result of Boundary Detection After Thresholding.

The proposed system will overcome the problems with 3D model due to moving parts. GFR measurement is done by using voxel deformation which is an important parameter in diagnosis. More accurate boundary detection is possible as carried out after segmentation. Finally diagnosis of renal diseases is expected by using the standard sets of rules are still to be defined. Results of some processing steps are shown for the system in figure 2.

Acknowledgments

References

[1]. F. Maes, A. Collignon, D. Vandermeulen, G. Marchal, and P. Suetens, “Multimodality image registration by maximization of mutual information,” IEEE Trans. Med. Imag., vol. 16, no. 2, pp. 187–198, 1997.
[2]. M. M. Fernandez, C. A. Lopez, “An approach for contour detection of human kidneys from ultrasound images using Markov random fields and active contours,” Elsevier B.V. 1361/8415/$, 2004.
[3]. A. Gholipur, N. Kehtarnavaz, “Brain functional localization: A survey of image registration techniques,” IEEE Trans. Med. Imag., vol. 26, no. 4, 2007.
[4]. A. Ali, A. A. Farag, and A. S. El-Baz, “Graph cuts framework for kidney segmentation with prior shape constraints,” LNCS 4791, pp. 384-392, Springer-Verlag Berlin Heidelberg, 2007.
[5]. De Priester, J. Kessels, A. Giele, E. den Boer, J. Christiaans, M. Hasman, A. van Engelshoven, J. ” MR Renography by semi automated image analysis: performance in renal transplant recipients. J. Magn. Reson Imaging 14(2), 134-140 2001.
[6]. Giele E. “Computer methods for semiautomatic MR Renogram determination,” PhD thesis, Eindhoven University of Technology, Eindhoven 2002.
[7]. Boykov, Y. Lee, V. S. Rusinek, H. Bansal, R. “Segmentation of dynamic N-D data sets via graphs cuts using markov models. In. Niessen, W. J. Viergever, M. A. MICCAI. LNCS, vol 2208, pp. 1058-1066,” Springer, Heidelberg, 2001.
[8]. Sun, Y., Jolly, M. P., Mourua, J. M. “Integrated registration of dynamic renal perfusion MR images,” In. Proce. IEEE ICIP, pp. 1923-1926. IEEE Computer Society Press, Los Alamitos, 2004.
[9]. A. A. Farag, W. Miller, H. Abdelmunim, M. aboelGhar, “A kidney segmentation approach from DCE-MRI using level sets,” IEEE 978-1-4244-2340-8/08, 2008.
[10]. F. G. Zollner, R. Sance, P. Rogelj, M. J. Lesma-Carbayo, J. Rorvik, A. Santos, A. Lundervold, “Assessment of 3D DCE-MRI of the kidneys using non-rigid image registration and segmentation of voxel time courses,” Elsevier, 2008.
[11]. N. V. Bukoreshtliev, T. W. Eichler, E. Hodneland, Xen-Cheng Tai, S. Gurke, A. Lundervold, “A unified framework for automated 3D segmentation of surface-stained living cells and a comprehensive segmentation evaluation,” IEEE Trans. Med. Imag., vol 28, no. no. 5, 2009.
[12]. A. Kefali, T. Sari, M. Sellami, “Evaluation of several binarization techniques for old arabik documents images,” University BadjiMokhtar, 2009.
[13]. M. Spigel, D. A. Hahn, V. Daum, J. Wasza, J. Hornegger, “Segmentation of kidneys using a new active shape model generation based on non-rigid image registration,” Elsevier, 2008.
[14]. D. R. Twining C, Cootes T, Waterton J, Taylor C, “3D statistical shape models using direct optimization of description length,” In: European conference on computer vision, vol. 3, p.3-20, 2002.
[15]. C. Callins Christiyana, V. Rajamani, “Comparison of local binary pattern variants for ultrasound kidney image retrival,” IJARCSSE vol. 2, issue 10, 2012.
[16]. S. Manikandan, V. Rajamani, “Analysis of ultrasound kidney image features for image retrival by gray level co-occurrence matrices” LNSE, vol. 1, no. 1, 2013.
[17]. J. L. Zhang, H. Rusinek, H. Chandarana, and V. S. Lee, “Functional MRI of the kidneys,” *J. Magn. Reson. Imag.* vol. 37, no. 2, pp. 282–293, 2013.
[18]. J. Tokuda, H. Mamata, R. R. Gill, N. Hata, R. Kikinis, R. F. Padera, R. E. Lenkinski, D. J. Sugarbaker, H. Hatabu, “Impact of nonrigid motion correction technique on pixel-wise pharmacokinetic

ISSN 2348 – 7968

analysis of free-breathing pulmonary dynamic contrast-enhanced MR Imaging, ” *J. Magn. Reson. Imag.* vol. 33, no. 4, pp. 968–973, 2011.

[19]. L. Bokacheva, H. Rusinek, J. L. Zhang, Q. Chen, V. S. Lee, “Estimates of Glomerular Filtration Rate from MR Renography and Tracer Kinetic Models,” J. Magn. Reson. Imag. 2011.

[20]. A. M. Khan, Ravi S., “Image segmentation methods: a comparative study,” IJSCE, ISSN: 2231-2307, vol. 3, issue 4, 2013.

[21]. E. Hodneland, E. A. Hanson, A. Ludervold, J. Modersitzki, E. Eikefjord, A. Z. Munthe-Kass, “Segmentation-driven image registration application to 4D DCE-MRI recordings of the moving kidneys,” IEEE Trans. on Imag. Proces. vol. 23, no. 5, 2014.

[22]. “Diagnosis and management of chronic kidney disease” Scottish intercollegiate guideline network, 2008.

[23]. J. S. Jose, R. Sivakami, N. U. Maheshwari, R. Venkatesh, “An efficient diagnosis of kidney images using association rules,” IJCTEE, vol. 2, issue 2, 2012.

[24]. Devidas D. Dighe, “Edge based segmentation using SUSAN edge detector” in national Conference “Intelligent Data Analytics And Image Processing (IDAIP-2007) held at Bannari Amman Institute of Technology, Tamilnadu Dt., 26-27 OCT 2007.

[25]. D. D. Dighe, J. J. Chopade, N. L. Bhale, “Image segmentation using SUSAN edge detector” In IEEE international conference “SPIT-IEEE Colloquium 2007 and International Conference” held at Sardar Patel Institute of Technology Mumbai on 4-5 Feb 2008.

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