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An innovative neural network framework to classify blood vessels and tubules based on Haralick features evaluated in histological images of kidney biopsy

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ABSTRACT

Introduction and objective: Computer Aided Diagnosis (CAD) systems based on Medical Imaging could support physicians in several fields and recently are also applied in histopathology. The aim of this work is to discuss in detail the design and testing of a CAD system for segmentation and discrimination of blood vessels versus tubules from biopsies in the kidney tissue through the elaboration of histological images.

Materials and methods: Materials consist in 10 Kidney Biopsy Slides (KBS) with Periodic Acid Schiff (PAS) staining. The Regions Of Interest (ROI) identified by expert are in total 221:71 vessels and 150 tubules. KBS preparation and digital acquisition have been conducted by expert technicians at the Department of Emergency and Organ Transplantation (DETO) of the University of Bari Aldo Moro (Italy). Each slice is a Red Green Blue (RGB) format image with a resolution of 0.50 µm/pixel. Starting from KBS images, several techniques were tested for ROI's segmentation and classification. In particular, we formerly describe the innovative preliminary step to segment regions of interest, the procedure to extract significant features from them and finally discuss the supervised Artificial Neural Networks (ANNs) architecture based on error back propagation training algorithm. All the training sets were builts by using vessels and non vessels (tubules) ROI samples, whose dimensions were correlated to the vessels to be detected.

Results: The performance of the best ANN architecture, trained by using a training set of 35 vessels among the 71 available vessels in dataset, were evaluated in terms of False Positives (FPs) and False Negatives (FNs). On an initial reduced dataset, it reveals good performance and robustness in terms of FPs reduction.

Conclusion: Tests determined that the supervised ANN approach is consistent and reveals good performance, after a training phase based on vessels and non-vessels (tubules) samples. Moreover, our method could be improved by using a larger dataset diagnosed by expert nephropathologists.

1. Introduction

Computer-aided diagnoses (CAD) are procedures in medicine that assist physicians in the interpretation of data such as medical images. These systems analyze the image to detect and characterize regions of interest, with the aim to help physicians to improve diagnostic accuracy and focus on the most suspicious areas of the candidate image in terms of pathology. CAD systems have been applied to several methods of diagnostic imaging [1], all of which are generally based on radiological images. Within a few years, this field of research will be also expanding in other medical fields, such as histopathology [2], where images are completely different from radiological ones. In this paper we present the design and the implementation of a CAD system for segmentation and discrimination of blood vessels versus tubules from biopsies in kidney tissue through the elaboration of histological images. For this purpose, we used renal biopsies harvested before implantation from kidneys of deceased donors to assess the suitability for transplant. Histological evaluation is indeed a routine practice of many transplant centers when donor age is more than 60 years or when there are comorbidities, such as diabetes or hypertension. In these cases, histological analysis of renal biopsy tissue is useful to assess if kidneys are suitable for single or double transplant or rather to be discarded. The Karpinski score is an histological score that assesses the degree of chronic lesions in each compartment of the renal parenchyma (glo-

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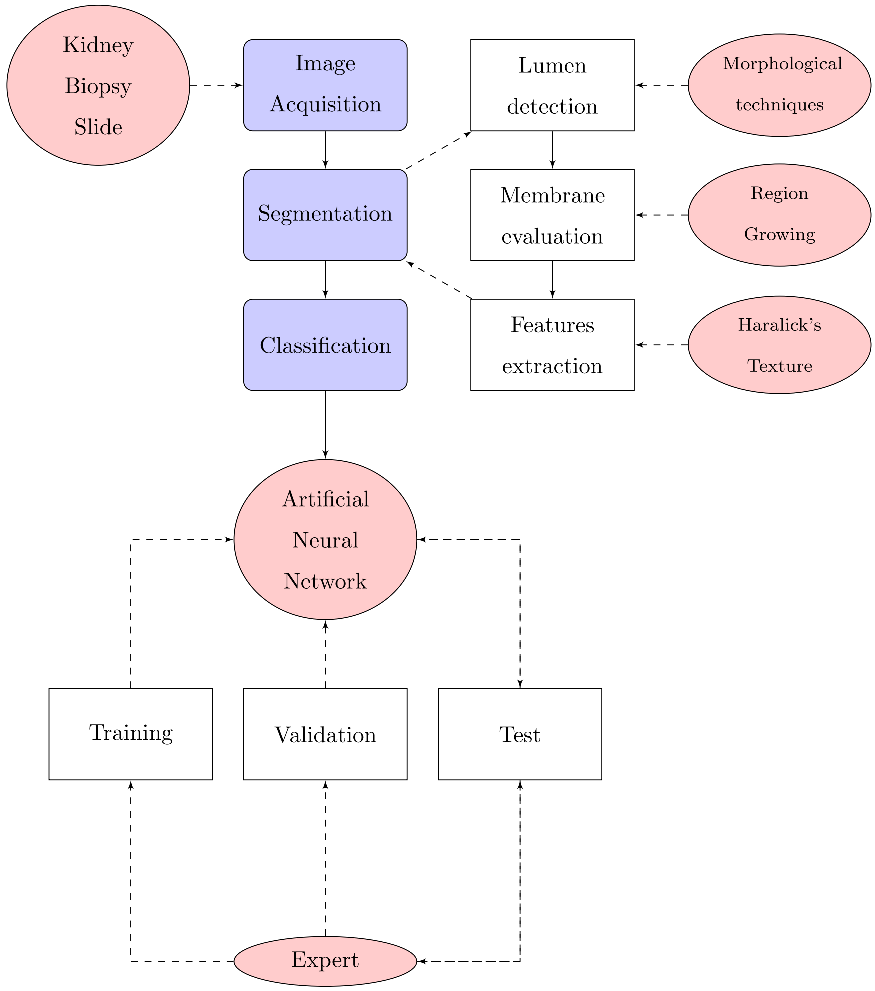

Fig. 1. Pipeline architecture. Red clouds are "input/output" systems. Rounded corners rectangles are main phases described in this paragraph. Rectangular blocks are sub-phases.

meruli, tubules, interstitium and vessels) [3]. A semi-quantitative score (from 0 to 3) is assigned to the degree of glomerulosclerosis, tubular atrophy, interstitial fibrosis and vascular sclerosis with narrowing of vascular lumina. High values of these parameters are associated with poor, early and late graft outcomes [4].

Computer aided histopathological studies have been conducted for various cancer detection and grading applications, including prostate [5,6], breast [5,7,8], renal cell carcinoma [9] and lung cancer grading [10,11]. Using different segmentation, feature extraction and classification techniques the researchers analyzed histopathology images.

Histological image processing and analysis is an emerging area which has more challenging problems, if compared with radiological image processing and analysis; in fact, due to the presence of many more visible tissues, the amount of information to process increases. Moreover, histological images are noisier than radiological ones.

The objective of the segmentation of vessels is to identify not completely closed vessels, on which it is possible to determine the vascular score.

The work presented in this paper is a single task of a wider project for the determination of all the four scores of Karpinski.

2. Histology image analysis – literature survey

The histopathological image analysis includes computations performed at different magnifications (×2, ×4.5, ×10, ×20 and ×40) for multivariate statistical analysis, diagnosis and classification. It can be done at lower magnification for tissue level analysis. In [12] the authors analyzed histopathology images using image preprocessing, feature extraction and classification techniques such as thresholding, morphological processing, both region and boundary based, and supervised classification techniques. Computer aided diagnosis algorithms have been proposed for neuroblastoma detection [13]; moreover, in [9] it was proposed a computer aided analysis of renal cancer image, based on Bayesian classifier and k-means algorithm, to improve inter and intra-observer variability in decision by pathologists.

Depending on the application or kind of disease, image processing steps may vary but, in general, image processing algorithms are similar for most of the applications. In histology, image segmentation [14] can mainly be used for detection of nuclei, stroma and background.

The texture approach for finding presence of disease in image sample for different cases in microscopic imagery is also very helpful. In [15] the author proposed a texture based technique to correctly classify meningioma tumors. The algorithm were based on optimum texture measure combination, which inspects the separation of the RGB color channels by selecting the one which best segments the cell nuclei of the histopathological images; subsequently, a Bayesian classifier was used for meningioma subtype discrimination.

After segmentation, features are extracted either at the cellular or at the tissue level to measure morphological characteristics of image for abnormality, or to classify the image for different grades of disease. In [6] the authors used textural and nuclear architectural features for analysis of breast cancer histopathology images. The different types of feature extraction techniques are: textural features using gray level, Haralick features, graphical features and Gabour filter features, graph features using Voroni diagram, Delauny Triagulation, Minimum Spanning Tree, Nuclear Features, morphological features, topological