

HPC Systems for Computer-Aided Medical Images Analysis

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Abstract. *Develop a system of automated computer diagnostic of skeletal metastases according to scintigraphy, based on the principles of recognition of images and that has the function of the expert analysis of medical images. The system includes a segmentation of the image of a skeleton, the calculation of the texture, histogram and morphometric parameters, creating a learning sample treated with medical images. The issues of evaluation of the quality of the images on the example of the images of the skeleton*

Keywords

Scintigraphy, segmentation, computer automated diagnosis, the quality of medical images.

1 Introduction

Progress in the development of bioinformatics and mathematical methods in biomedicine, as well as the development of computer and telecommunications systems and networks determines the look of the present and future of medical technology and of medicine in general [8, 10]. At last years of one of the directions of development of cloud computing technologies in high-tech-medicine is a processing the digital image: improvement of quality of image, recovering image, its recognition of separate elements.

Recognition of pathological processes is one of the most important problems of processing the medical image. By now, a number of standards for medical imaging have been developed [15]. By analogy with CAD/CAM systems (computer aided design and computer aided manufacturing) for technical applications, CAD (computer-aided diagnosis) systems are being developed for medical purposes [9,12,13]. Some of them are already successfully operating, but to date these systems are only «assistants» of a diagnostician who takes decisions. CAD algorithms for medical imaging systems typically include image segmentation, the selection of some objects of interest («masses»), their analysis, parametric description of the selected objects and their classification.

2 Related works

To date, various methods for quantitative evaluation of image based on the calculation of parameters such as sharpness, contrast, noise, etc. but an attempt to use them to calculate the quality of the images in the images of the skeleton of the head, chest, spine, pelvis, large joints did not give an adequate answer in relation to the subjective evaluation of experts. To evaluate the image quality of the skeleton to use absolute image quality evaluation (that is, without comparing it with the reference image). Thereby created an automatic system that allows you to enhance the diagnostic efficiency analysis of planar scans of the skeleton on the basis of bone scan.

3 Main sections

The classification of objects of interest may be made by the method of neural networks, support vectors, discriminant analysis [2, 12, 14] etc. CAD systems significantly increase the effectiveness of radiographic diagnosis methods. However, the practical application of nuclear medicine demonstrates the continued information deficiency of the algorithms and programs that provide visualization and analysis of medical images. This is especially noticeable when the radionuclides, which are used, do not have a high capacity for accumulation in the pathological area. These include the bone scintigraphy method. Whole-body planar scintigraphy with ^{99m}Tc-labeled phosphate compounds is widely used

in the diagnosis of skeletal metastatic disease. Combining with crystals of hydroapatite, phosphate compounds reveal tumor-associated osteoneogenesis and can detect bone metastases long before the demineralization and bone destruction is detected by the X-ray examination [12]. In addition, various pathological processes in the skeleton, as well as metastases, are revealed as polymorphic zones of hyperfixation (further referred to as PZH) of radiopharmaceutical preparations (further referred to as RPP). Despite the fact that bone scintigraphy is a method of choice in the early diagnosis of skeletal metastases of the tumors that tend to spread to the skeleton, the interpretation of bone scans in cancer patients is rather complicated.

Early diagnosis of metastatic lesion of the skeleton has a significant influence on the choice of treatment of patients with malignant tumors. Therefore, there is a need to search for an approach to the optimization of scintigraphy analysis. The use of CAD analysis could substantially improve the specificity of osteoscintigraphy. At the same time work on the application of CAD systems in the scintigraphy of the skeleton are rare and are not performed in this country [13]. The aim of the study was to determine the principles of optimizing the processing of planar osteoscintigraphy on the basis of CAD analysis. The results of scintigraphy are presented as plain (gray) digital images. In this case, a pixel image matrix can be the object of the analysis where each point (pixel) has a numerical value of brightness. Brightness value indirectly characterizes the intensity of the detected radiation (the amount of gamma photons identified by the detector) in each point of the object under study. The functional diagram CAD system that was developed included the following components: (1) – image input; (2) - segmentation of the image and storing it in the archive; (3) – identifying diagnostic features (characteristics) of the segmented images of the archive; (4) – the formation of the training set and storing it in the archive; (5) – the formation of the classifier; (6) – the classification of new segmented areas of the image.

In the study we used the scans of the patients with skeletal metastases of breast cancer, performed in a planar mode with Infinia-Hawkeye, the two-detector gamma camera manufactured by General Electric, using RFP pirfoteh-99mTc. The original image of the skeleton was recorded in the format of DICOM, which is central for the representation of medical images. Further analysis of the images was carried out in the program created in MATLAB [6]. In this case, the original image is preserved in a matrix form in the shape of the internal MATLAB format [2]. A significant role in the CAD image analysis was played by a segmentation method which helped to delineate the area corresponding to the skeleton. This segmentation was performed manually because to date there are no effective methods of automatic segmentation of complex anatomical objects. The mean value of image brightness was determined in the area corresponding to the skeleton, as well as the standard deviation (σ) of the value.

It is a common point of view that the main feature of metastatic lesions on scintigraphy is a local hyperfixation of radiopharmaceutical preparation (RPP). The segmentation of RPP hyperfixation zones was conducted in the area corresponding to the skeleton and performed either automatically or manually. At the same time, the study adopted the hypothesis that pixels brightness values which were equal to or exceeded 2σ of the mean brightness value of the entire skeleton were considered as RPP hyperfixation which corresponded to a metastatic lesion. The range of brightness values corresponding to metastases was programmatically specified. The areas with a given range were marked on the scans. The automatic segmentation which determines the RPP hyperfixation areas was made by the «threshold» method [2]. In addition, the lesions suggestive of metastases in which the brightness value was less than 2σ were manually segmented. Identifying diagnostic features (characteristics) of segmented images is an important part of the functional scheme of the CAD system that was developed. Histogram, morphometric and texture parameters are calculated in the system by the methods of Haralik [3,4]. and local binary texture [2,11,14].

A group of histogram parameters includes the mean brightness value of the image, the standard deviation of the brightness from its mean value (σ), smoothness, the third moment of brightness, uniformity and entropy in the areas of RPP hyperfixation of the images [2,7]. The second group of symptoms is characterized by spatial texture brightness in PZH (polymorphic zones of hyperfixation). A so-called statistical approach, first proposed by R.M. Haralik in [3,4] was used. This approach makes it possible to create texture characteristics taking into account the distribution of brightness in the neighboring pixels of PZH. Textural characteristics are calculated on the basis of conjugate brightness level of an image in the local rectangular box and stored in a matrix of conjugate brightness levels, Grey Level Cooccurrence Matrix (GLCM), according to the principle described in [14]. The indicators included in this group of features are represented by the dispersion of mean values used in the X and Y axes of digital image matrix, contrast ratios, autocorrelation, correlation, heterogeneity, homogeneity, energy, entropy, maximum likelihood, reciprocal difference and so on. The third group includes the texture parameters determined by the method of local binary texture [10]. The fourth group consists of the following morphometric parameters: the ellipsoidal coefficients of PZH, compactness and eccentricity of PZH [2].

After image segmentation isolated areas of PZH are analyzed by experts and are divided by them into metastatic lesions and non-metastatic areas. At the next stage the training set consisting of PZH objects is analyzed by an expert. Calculated histogram, texture and morphometric parameters corresponded to each object in the training set [5]. The training set included 169 front and 110 rear scans showing the distribution of radiopharmaceutical in the front and rear

parts of the skeleton. The data on the RPP hyperfixation areas, the numerical values of which were included in the training set are presented in Table 1.

Tab. 1. The volume of the training set used to create the classifier for scans.

Scanning plane	The areas of radiopharmaceutical hyperfixation	
	Metastatic	Non-metastatic
Front	432	1185
Back	223	734

As an algorithm for the recognition of PZH (dividing them into metastatic and non-metastatic) the method of support vectors is used. It helps to create a classifier based on the training set (classifier function). Separate classifiers for the objects of front and back scans are also created. The evaluation of the quality of the classifier is carried out using ROC-curve expressing the ratio of true and false findings [9]. The result of checking the effectiveness of the classifier on a test set of RPP hyperfixation areas using ROC-analysis is presented in [7,9].

The algorithm of the unit for recognizing the new objects of PZH involves a sequential completion of the following stages: image segmentation (1), the calculation of diagnostic features for a new sample of objects (2), the use of the classifier to the selected sample of objects (3) and calculating the reliability of the classifier with respect to the sample (4). The result of the third phase of the program is the distribution of the objects of the analyzed image into two groups: metastatic and non-metastatic. The reliability of the classifier with respect to the sample was determined with the help of predicted variables classifier (PLVC), the method of calculation is presented in [1]. PLVC values range from 0 to 1 [9]. At the same time, the closer the PLVC value, calculated for a particular object, is to 0 or 1, the more likely the object in question can be attributed to metastatic or non-metastatic. As an example, the analysis of patient N's data is presented. Figure represents the patient's planar osteoscintigram in which a manual segmentation of the skeleton has been performed.

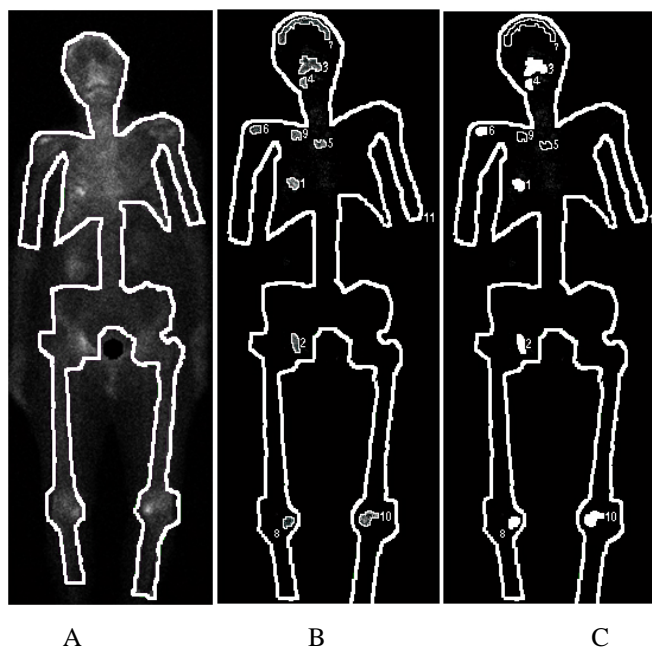


Fig.1. Planar bone scintigrams of patient N:
a - Segmentation of the skeleton;
b - Segmentation of RPP hyperfixation areas;
c - automatically segmentation of RPP hyperfixation areas.

The results of recognizing RPP hyperfixation areas using an expert system (filling – «metastatic» lesions, no filling - nonneoplastic hyperfixation). Fig.2c shows the segmentation of RPP hyperfixation areas that was performed automatically. The pixels, whose brightness values were equal to or exceeded 2σ of the average brightness of the entire skeleton, were treated as lesions suspicious for metastases. As can be seen in Fig.2b, 10 areas of RPP have been segmented. To determine their nature in relation to the given sample the classifier, developed on the principle presented earlier, was used. In fact, the problem of image recognition has been solved with the help of the expert system, in which the expert's ideas of visible signs of metastatic lesions were expressed in numerical values of histogram, texture and morphometric parameters. The recognition results are presented in Fig.2b. As can be seen from the fig.2c, 7 out of 10

areas of RPP hyperfixation had signs of metastases. However, a more definite judgment on referring the areas to metastatic lesions can be made with the help of PLVC analysis.

The CAD system under study has the functions of expert analysis and is based on the principles of image recognition. This is very important for the analysis of bone scans, where pronounced polymorphism of RPP hyperfixation areas creates significant difficulties for the correct visual evaluation of the data obtained with the help of skeleton scintigraphy. In such CAD system the expert's ideas of visual signs of metastatic lesions are expressed in numeric values of histogram, texture and morphometric parameters. This is the basis of objective classification of the analyzed images. The principal difference between the system under analysis from the most well-known CAD system proposed by M.Sadik for the evaluation of skeleton scans [13], is the calculation of predicted latent variability of classifier (PLVC) for RPP hyperfixation areas on scans [5,7]. Thus, not only those RPP hyperfixation areas that are definitely abnormal (in this case - metastatic) can be distinguished, but also those whose nature needs specifying through further research and monitoring. PLVC calculation may be important in the clinical use of the CAD system. Naturally, the established system requires in-depth lab testing on different categories of patients and healthy individuals. However, now we can conclude that its diagnostic capabilities are largely dependent on the qualifications of the expert. Another factor affecting the accuracy of the recognition of metastatic lesions in the skeleton, is the size of the training set, which can be increased significantly with time. Therefore, increasing the use of the system is one way to increase its diagnostic reliability.

4 Conclusion

The CAD system can successfully analyze (to improve the efficiency of the analysis) planar skeleton scans on the basis of automated computer diagnosis by increasing the diagnostic value of bone scintigraphy method. Automatic diagnostics of RPP hyperfixation areas requires a classifier function based on numerical analysis of texture, morphometry and histogram parameters using the support vector method as a recognition algorithm. The accuracy of recognizing RPP hyperfixation areas can be determined with the help of PLVC indicator (predicted latent variables of classifier).

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