ULTRASONIC MULTIFEATURE TISSUE CHARACTERIZATION FOR PROSTATE DIAGNOSTICS

U. Scheipers[1*], H. Ermert[1], A. Lorenz[1,2], A. Pesavento[1,2],
H.-J. Sommerfeld[3], M. Garcia-Schürmann[3], K. Kühne[3], T. Senge[3] and S. Philippou[4]

[1] Lehrstuhl für Hochfrequenztechnik, Ruhr-Universität Bochum, Germany
[2] LP-IT Innovative Technologies GmbH, Bochum, Germany
[3] Urologische Universitätsklinik, Marienhospital Herne, Germany
[4] Institut für Pathologie, Augusta-Krankenanstalt Bochum, Germany

[*] ulrich.scheipers@ruhr-uni-bochum.de

Abstract – The incidence of the prostate carcinoma is one of the highest cancer risks in men in the western world. Its position in cancer mortality statistics is also among the highest. The prostate carcinoma is only curable at an early stage. Therefore, early detection is extremely important.

The different types of diagnostics that are used today (digital rectal examination, transrectal ultrasound and PSA value analysis) lack reliability and are therefore not sufficient.

Diagnosis of the prostate carcinoma using multi-feature tissue characterization in combination with ultrasound allows the detection of tumors at an early stage. Two adaptive neuro fuzzy inference systems (ANFIS) are used in parallel to classify the prostate tissue and locate tumors.

I. METHODS

Data Acquisition

Radio-frequency (RF) ultrasonic echo data of the prostate is captured during the usual examination of the patient with standard ultrasound equipment (Kretz Combison 330, transrectal probe, 7.5 MHz center frequency). The RF-data is directly transmitted to a PC, sampled at 33 MHz and 12 bits, subdivided into up to 1000 segments per prostate slice and compensated for depth and system dependent effects using the inverse transfer function of the system.

Parameter Extraction

Up to 40 parameters are calculated for each segment. The parameters used for classification are calculated from the frequency spectrum and from the time domain. Spectrum parameters are calculated after applying a Hamming window to the RF data, computing the Fourier transform and converting the resultant power spectrum to dB. The primary set of spectrum parameters consists of measures of backscatter calculated for the signal bandwidth (slope, axis intercept and midband value). Parameters of an attenuation model (multi narrow band method) are also included in the system. The texture parameters consist of first and second order (cooccurrence) parameters.

Initial results have shown that only a combination of these different fields of descriptors leads to adequate classification results. During the preselection procedure of parameters for the training process of the system, parameter vectors that are highly dependent on each other are found and discarded using covariance matrix analysis. During the preselection the number of parameters is reduced from 40 to 16 for both fuzzy inference systems.

System Description

Two fuzzy inference systems (FIS) working in parallel classify and separate the segments into two classes (benign, malign). The fuzzy inference systems used in this work are based on Sugeno type systems with up to six Gaussian membership functions per input parameter. The number of required rules is chosen adaptively by the system. The fuzzy output maps of the two fuzzy inference systems are transformed into binary 1/0-maps applying a threshold to divide the two classes. The threshold can be chosen freely by the operator. A following morphological analysis combines clusters in the binary output maps of the fuzzy inference systems to mark areas of similar tissue characteristics. The results of the two fuzzy inference systems are combined to build a malignancy map, which consists of a traditional B-mode image in which areas of a high cancer probability are marked in red. The malignancy map (Figure 1) is presented to the physician during the examination on a PC screen and thus can supplement the existing methods of diagnostics. Malignancy maps can easily be printed or archived for biopsy planning.

II. CLINICAL STUDY

During a clinical study, radio-frequency ultrasonic echo data of 100 patients undergoing clinical examinations have been recorded. Prostate slices with histological diagnosis following radical prostatectomies act as the gold standard. The RF datasets have been divided as described above resulting in 130,000 benign and 40,000 malign segments. Cancerous areas have been stained and marked on the prostate slices. Malign areas have been encircled by the pathologists (Figure2). The contours have been transferred to the PC by experienced physicians thus making a definite assignment of dataset segments to tissue classes possible (Figure 3).

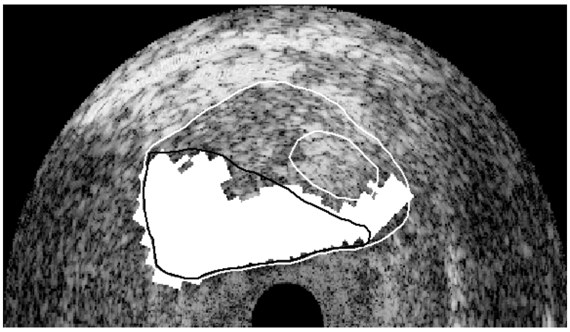

Figure 1: Overlay of B-mode image and malignancy map. Areas of a high cancer probability are marked white.

For classification reasons the tumors have been divided into two different classes. The first class consists of all tumors that were visible in the classical B-mode image. Hypoechoic appearing tumors have as well been included in this class as hyperechoic appearing tumors. The second class consists of all tumors that were not visible in the classical B-mode. Prior work has shown that the partitioning of the entire amount of malign segments into these two classes improves the classification results quite significantly. The third class consists of all other kinds of tissue. Next to normal tissue segments also segments that consist of benign prostate hyperplasia belong to this class.

Figure2: Histology, tumors have been stained, malign and benign tissue areas have been marked by pathologist

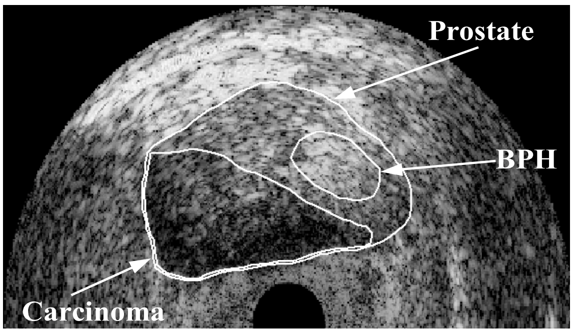

Figure 3: B-mode image with contours.

Successively two fuzzy inference systems have been trained. The first system was trained to distinguish the first class from the third class. The second system was used to distinguish between the second and the third class.

III. RESULTS

Each of the two fuzzy inference systems yields a fuzzy value for each segment of the ultrasound dataset. The fuzzy value is a measure of the probability of a segment that consists of a defined tissue type to be malign or benign.

As the classification procedure applied here represents a continuous system, sensitivities and specificities can be chosen freely under dependence of each other.

The ROC curve area is $A_1 = 0.83$ for the first system and $A_2 = 0.76$ for the second system respectively. The capability of the system has been determined using the leave-one-out classification method.

IV. CONCLUSION

It has been shown that our system for ultrasonic multifeature tissue characterization is able to detect the prostate carcinoma with a high grade of accuracy. Thereby the system can supplement the existing methods of prostate diagnostics to improve the early detection of prostate cancer and allow a more reliable diagnosis. The planning of biopsies can be improved, unnecessary biopsies can be avoided and performed biopsies can be guided more reliable.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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