METHOD OF DETECTING ELASTICITY VARIATIONS AND ECHOGRAPHIC APPARATUS FOR CARRYING OUT THE METHOD

FIELD OF THE INVENTION

The invention relates to a method of detecting elasticity variations in a soft tissue which is subjected to an external compression in a predetermined axial direction.

The invention also relates to an echographic apparatus provided with means for carrying out the method.

The invention is used in the medical imaging industry.

BACKGROUND OF THE INVENTION

A method of reconstructing tissue elasticity while using linear perturbation is already known from the publication "Tissue Elasticity Reconstruction Using Linear Perturbation Method" by F. Kallel and M. Bertrand, IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 15, No. 3, JUNE 1996, pp. 299–313. Said publication describes a method of reconstructing the elasticity modulus of a soft tissue, which is subjected to a static external compression, on the basis of measurements of displacements caused by said compression. Said method utilizes a known algorithm for solving an inverse problem; this algorithm is called the Newton-Raphson algorithm and utilizes a direct relation which yields the image of a set of displacement fields by way of a Finite Element Model of elasticity equations and adapts said direct relation, in a least squares sense, in order to provide the distribution of the corresponding elasticity moduli. The set of axial displacement fields of tissues forms the basic data which is estimated in advance while utilizing a multi-bit correlation technique which is applied to ultrasonic signals. The problems relating to the matrix enabling the solution of the inverse problem according to the Newton-Raphson algorithm are taken into account while utilizing a known so-called Tikhonov regularization technique which utilizes the identity matrix I. A regularization technique is used so as to realize a compromise between the reliability of the data observed and the a priori information of the solution. Utilizing an echographic imaging model, said publication teaches that the algorithm converges in from 10 to 15 iterations. Figures of the cited publication show images of the elasticity modulus distribution obtained in 15 iterations by reconstruction on the basis of noisy data while utilizing the Newton-Raphson algorithm regularized for each iteration by the Tikhonov term with I.

SUMMARY OF THE INVENTION

In the field of medical diagnosis of anomalies in soft tissues, malignant tumors are distinct from healthy tissue and from benign tumors that the elasticity of these tissues differs; this difference is due to their different structure. In the field of breast cancer diagnosis it is particularly interesting to have a non-invasive measuring method available which is exact as well as reliable for the detection of malignant tumors, that is to say skin deep tumors as well as very deep tumors and starting tumors of very small diameter which are very difficult to detect.

It is a problem that the distribution of the elasticity modulus in a soft tissue cannot be measured directly. Only the field of displacements due to a compression of the soft tissue can be measured. However, such displacements are extremely small, so that the measurements thereof cannot be used directly by a practitioner. Conversely, the elasticity modulus distribution forms a set of data which is very interesting because of the fact that this data offers suitable information as regards the nature of the tissues and has a significant contrast which can be readily used and is linked to the measurements of displacements caused by a compression of the soft tissue. Another problem is that the elasticity modulus distribution is not linked to the data of the displacement field by way of a direct relation. On the other hand, the data of the displacement field is linked to the elasticity modulus distribution by way of a direct relation, with the result that the elasticity modulus distribution in a tissue must be calculated by means of a method for solving the inverse problem on the basis of data of the displacement field. A method of solving an inverse problem is already described in the cited publication. It is a problem that this known method is not exact enough for use for the detection of malignant tumors by determination of the elasticity modulus distribution in tissue, because the measured data of the displacement field is very small and the presence of the noise during the acquisition of this data is extremely pronounced.

Therefore, the invention proposes a detection method as disclosed in claim **1**.

This method offers reconstruction images of elasticity variations in the tissue which are far less noisy, have more contrast and hence enable the detection of very small elasticity variations which correspond to inhomogeneities of the tissue, and hence enable better localization of these defects. This offers improved possibilities for applying this method for the detection of very small tumors.

The method is advantageously carried out by means of an echographic apparatus which constitutes a non-invasive diagnostic tool.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail hereinafter with reference to the accompanying diagrammatic drawings; therein:

FIG. **1** shows a block diagram of the systems carrying out the steps of the method for detecting inhomogeneities in tissue;

FIG. **2** shows a block diagram of the systems carrying out the functional steps for reconstructing the elasticity modulus distribution on the basis of the displacement field;

FIG. **3** shows iso-displacement lines of a displacement field, calculated on the basis of echographic signals acquired during the compression of an explored tissue;

FIG. **4** shows an image of the variations of the elasticity modulus in a tissue with two inhomogeneities;

FIGS. **5**A, **5**B show an image of the variations of the elasticity modulus obtained by the linear Newton-Raphson method regularized by means of a regularization method according to the invention in the case of signal-to-noise ratios equal to 50 and 20, respectively, with a single iteration and in conformity with FIG. **4**;

FIGS. **6**A, **6**B show an image of the variations of the elasticity modulus obtained by the Newton-Raphson method regularized according to the Tikhonov method in the case of signal-to-noise ratios equal to 50 and 20, respectively, and in conformity with FIG. **4**, for the purpose of comparison with the FIGS. **5**A, **5**B.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention relates to a method for the processing of an echographic signal in order to detect inhomogeneities in an