

Simplified Wide-Range Ultrasonic Measurements Using the Sensor Three-Dimensional System

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Abstract

We developed a simplified three-dimensional ultrasonic device that can scan a wide area and performed measurements in the scanned area. The system is more compact than magnetic resonance imaging (MRI) systems and can measure random cross sections by acquiring volume data over a wide range through freehand scanning with a magnetic sensor unit that detects the transducer position. The system was applied successfully to a case with a huge myoma. Our system, in ways similar to computed tomography or MRI systems, can support both the objective understanding of the pathology of huge tumors and follow-up determinations of tumor diameters at arbitrary cross sections in the volume data.

Keywords: Three-dimensional imaging, freehand scanning, magnetic sensor, multiplanar reconstruction, ultrasound

INTRODUCTION

Ultrasound is an extremely useful diagnostic tool that has a wide use because it is minimally invasive. Recently, three-dimensional (3D) ultrasound devices have become widespread because of their clinical utility for 3D imaging and quantitative 3D data acquisition.^[1] Usually, 3D probes are employed to acquire quantitative 3D data, but such methods have restricted scanning areas. Consequently, it is not possible to use such 3D probes to acquire volume data that include the target while covering a wide target area. Riccabona *et al.*^[2] proposed a method for acquiring wide-range images through freehand scans using a magnetic sensor, a technique called extended field-of view ultrasound. However, the constructed images are two-dimensional, wide-area images, and measurement is not possible. Although a method for capturing volume data with freehand scanning has been reported, the captured range is restricted, and this method does not offer significant advantages over 3D probes.^[3]

We developed the Sensor 3D System to measure random cross sections by acquiring volume data over a wide range through freehand scanning and using a magnetic sensor unit to detect the transducer position. In this note, we present this system's application to some example cases.

METHODS

Ultrasonic three-dimensional display technique using the Sensor 3D System

The Sensor 3D System generates and displays 3D reconstructed image data (i.e., volume data) by appending positional information, obtained from a magnetic sensor attached to the transducer, to each freehand-scanned ultrasonic image.

Figure 1 shows a schematic diagram of the experimental Sensor 3D System. The magnetic sensor unit consists of an electric sensor module, magnetic field generator, arm for the magnetic field generator, and magnetic sensor. The electric sensor module is mounted on the ultrasonic diagnostic device (Aplio™ 500, Canon Medical Systems Corp., Otawara-Shi, Japan). The magnetic field generator is positioned near the patient, and the position and direction of the magnetic field generator are set by adjusting the arm while the magnetic sensor is attached to the transducer. Figure 1b shows the magnetic sensor, which is fitted to the probe with an adapter.

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The figure also illustrates an example application of the convex probe (PVT-375BT, Canon Medical Systems Corp., Otawara-Shi, Japan) to the abdominal region.

Figure 2 shows a conceptual drawing of the Sensor 3D System, which allows the physician to move the probe freely so that the B-mode scans can have arbitrary relative locations. As the probe is moved, the B-mode scans are captured and stored in the ultrasound system. A magnetic sensor measures the position of the magnetic sensor mounted on the probe relative to the magnetic field generator. The relative location of each scan plane is calculated, and the B-mode scans are combined into a single set of volume data. The Sensor 3D System works by collecting B-mode scan images with position information for five or more frames; it acquires angle information as well for each frame. In addition to the position of each frame, each pixel is arranged in 3D space, taking into consideration the angle, and it is reconstructed into 3D data by appropriate interpolation processing.

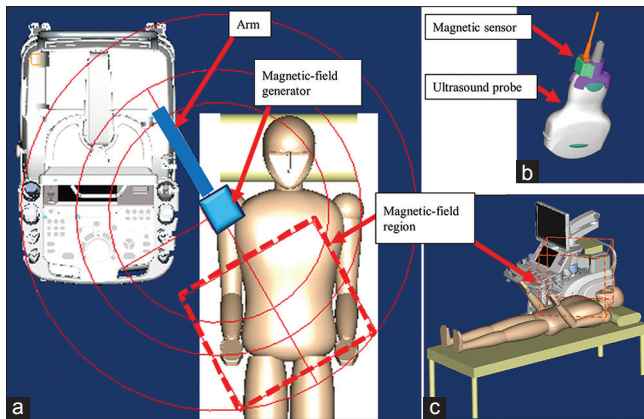


Figure 1: Schematic diagram of the Sensor 3D System. (a and c) Entire Sensor 3D System; red broken lines show the magnetic-field region created by the magnetic-field generator. (b) Ultrasound probe equipped with a magnetic sensor

The ultrasonic diagnostic device outputs 3D displays from the volume data. Two methods produce 3D displays: multiplanar reconstruction (MPR) generates a random section of 3D data and rendering method projects 3D images onto a two-dimensional plane so that they appear 3D. Figure 2 shows three orthogonal sections obtained using MPR and a rendering method with the ultrasonic diagnostic device. The MPR display can be used to measure random cross sections.

Scan area established using a computer

The computer used in the proposed system can store 1000 frames in memory to produce the ultrasonic tomographic image. When the frame rate of the abdominal portion probe in the B-mode is 20 Hz and the rate of movement of the probe is 10 cm for 10 s, 200 frames are captured per 10 cm; thus, an acquisition length of 50 cm is possible.

Scan area established from the recommended magnetic field space

The magnetic field strength generated by the magnetic field generator is 600 mG (terrestrial magnetic field of 600 mG or less, which is the same as that of Earth’s magnetic field). The magnetic field space created by the magnetic generator [Figure 1a and c] has a recommended space for positional information acquisition. In relation to the front face of the magnetic generator, the recommended space spans ±28 cm in the horizontal direction, ±30 cm in the vertical direction, and 20–66 cm in the depth direction. In this region of the magnetic field, the positional accuracy is 1.4 mm.

As shown in Figure 1a and c, the 60-cm-long range in the depth direction from the magnetic field generator becomes the magnetic field space; thus, ultrasonic observation with high positional accuracy becomes possible for at least the entire abdominal region. The 50-cm-wide range established with the computer technique is within the recommended magnetic field space of 60 cm.

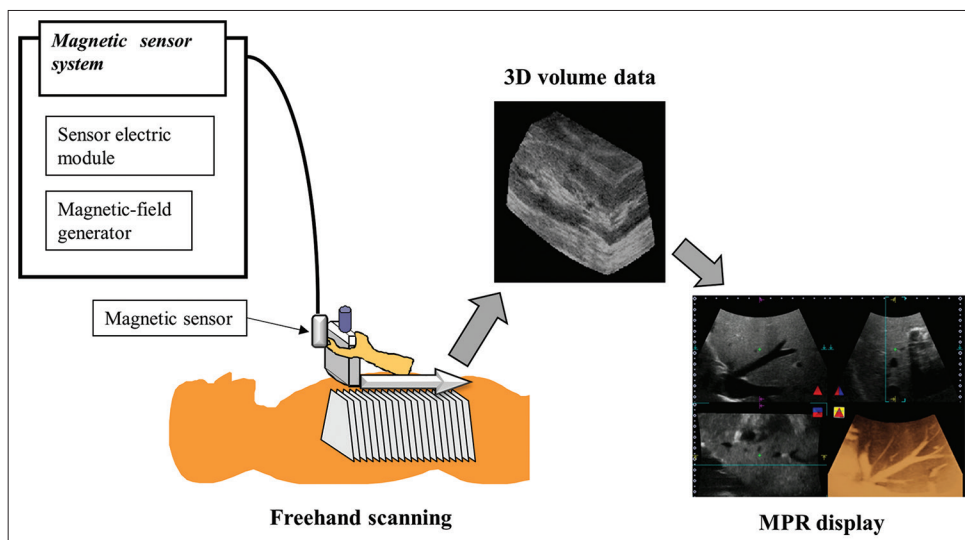


Figure 2: Function linkage of the Sensor 3D System

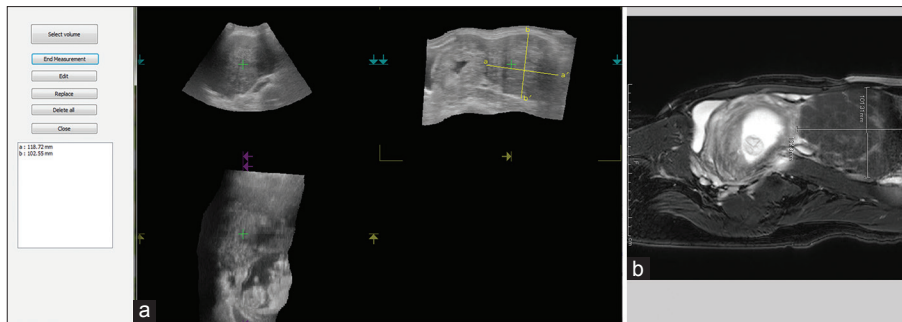


Figure 3: Example application of the Sensor 3D System. (a) Multiplanar resolution display. (b) Magnetic resonance image

RESULTS

Clinical application

We applied the Sensor 3D System to a clinical case as an example. The present study was approved by the Institutional Review Board of Kyushu University (No. 27-51), and informed consent was provided by the patient prior to the start of the study.

The subject was a pregnant uterus (12-week pregnancy) with a huge myoma of the uterine fundus. The acquisition length was 26.2 cm in the scanning direction. The measured dimensions of the uterine myoma were 119 mm × 102 mm × 98 mm [Figure 3a]. The dimensions of the image obtained with an magnetic resonance imaging (MRI), 132 mm × 101 mm × 100 mm [Figure 3b], were close to those obtained with the Sensor 3D System.

DISCUSSION

The Sensor 3D System enables the acquisition of random wide-area volume data and measurements of the volume; such determinations are difficult to perform with the existing 3D ultrasound systems. For example, the system is useful for capturing an image encompassing a huge uterine myoma; obtaining a one-screen image of such a condition is difficult with the ultrasonic B-mode. The proposed system enables the objective understanding of the pathology of huge tumors. It also allows for a follow-up observation of the tumor diameter at an arbitrary cross section in the volume data, as in the cases of computed tomography and MRI. For example, MRI is

currently used to determine the effects of hormone therapies on huge uterine myomas and their follow-up observations.^[4] However, the frequent use of MRI is not possible in ordinary medical environments. If follow-up observations could be performed with an ultrasonic device, such observations would be both simple and useful. Furthermore, the Sensor 3D System equipment attached to the ultrasonic device is small; thus, it can be used in many medical institutions where installing MRI systems is difficult. If this system becomes popular, its range of applications can be extended.

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Conflicts of interest

There are no conflicts of interest.

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