Control System of the Scanning Magnetocardiography

Jun-wei DU¹,², Qing-meng WANG², Dong-xu YANG¹,² and Tao SONG¹,²,*

¹University of Chinese Academy of Sciences, Beijing 100149, China
²Beijing Key Laboratory of Bioelectromagnetics, Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100190, China

*Corresponding author

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Abstract. The magnetocardiography (MCG) is a noninvasive diagnostic tool for cardiac current activity. The clinical investigation shows the MCG has better detection results than ECG and could reveal more information about the heart. The multichannel MCG could cover enough surface area of the chest, but at the same time will increase the cost of the system, which is one of the critical reasons why MCG cannot be widely promoted. In this study, a scanning magnetocardiography system was developed oriented towards low cost, which can detect enough area by the scanning method. The control system realizes the control of the hardware and the processing of the data and can complete the detection of MCG automatically. The effectiveness and reliability of the control system are provided by experiments.

Introduction

Heart disease is still one of the major diseases that endanger human health. The magnetocardiography (MCG) has been proved to have advantages over electrocardiogram (ECG) in the clinical diagnosis of some heart diseases [1, 2], such as myocardial infarction [3], ischemic heart disease [4], arrhythmias [5], chronic stable angina [6], and fetal heart diseases [7, 8]. The MCG signal is so weak which is millions of times smaller than the ambient magnetic field. So the low-temperature SQUID sensors which work in the liquid helium are often used as the key component of MCG system because of the high sensitivity.

Sufficient measurement area upon the chest to get enough information about the heart magnetic field, so the multi-channel MCG systems have emerged [9]. However, with the increase in the number of channels, the costs of the SQUID sensors and the amount of liquid helium consumed when working will increase, which makes the cost of MCG system increase. In this paper, we added the automatic control into the MCG system and designed a scanning automatic detection system, which could achieve an accurate, fast and large area detection. The control system realized the control of the moving unit, the detecting unit, and the data processing unit, and the MCG signal was detected in the experiment.

Frame of the Control System

The Scanning MCG system has been developed using in the unshielded environment, which is shown in Figure 1. It contains SQUID detection Unit, ECG detection unit, Movable bed unit, Data acquisition unit, and control software. The schematic diagram of the system is shown in Figure 2.
The SQUID detection unit includes a three-axis magnetometer and six SQUIDs connected to the second order gradiometer coils. The gradient coils are used to detect the MCG signal, and the magnetometer is used to detect the background field as the reference signal to eliminate the background noise. Three coil frames of the coil arrays are wound into a second-order gradiometer that measures only vertical signals, and the other one coil frame is wound into three sets of second-order gradiometers that could measure orthogonal three-direction signals. The ECG detection unit could detect ECG signal, which is used as the synchronous signal to average multiple periods of MCG signal.

The data acquisition card (DAC) is the PCI 8018 (ART, China), which has 16 AI ports and can realize simultaneous acquisition of all channels. The sampling rate is 1k Hz. We used the AI0 – AI8 ports for MCG signals, and the AI9 for the ECG signal.

The movable bed unit moves the human body in the horizontal plane. Two sets of motors are used in each direction to drive the bed. The USB 5932 (ART, China) sends DO signals to relay module to control motor switches. Each motor is equipped with an encoder which is connected to the PCI 2394 (ART, China) to monitor the position of the bed movement, and a closed-loop system is formed in cooperation with the relay module, which can accurately control the movement track of
the bed. The moving distance in each direction can be up to 50 cm, and the moving precision can be up to 0.5 mm.

**Control Strategy**

The MCG generally needs to measure the magnetic field signal of the heart at 36 points in front of the human chest (Figure 3), and the distance between the probe and the chest is about 1.5 cm. The ECG signal is acquired synchronously. This system can measure the MCG of four points at a time. Combining the detection unit and the movable bed, the system can realize the scanning detection and obtain the signal of the MCG of 36 points.

![Figure 3. The schematic diagram of 36 points of magnetocardiogram.](image)

The step (1) is to prepare the measurement. Move the movable bed to the farthest edge to make it easy for people to lie down and then find the start position. In general, the first point (A1) is set on the body's central axis, below the chin 5-10 cm.

After setting the initial point, the step (2) is to detect the MCG and ECG signals. Open the acquisition function, perform 30 seconds detection at the first position (A1, A2, B1, B2), observe the collected data in real time, and re-execute the detection at this position if there is an abnormal situation. After the acquisition, step (3) is the movable bed carries the body to the next position (A3, A4, B3, B4). Repeat the acquisition and move steps in the order (I to IX) shown in Figure 3 until the last point. The final step is to process the acquired signal to obtain the MCG and ECG signal. The action sequence of the measurement is shown in Figure 4.

![Figure 4. Action sequence of the acquisition.](image)

**Software Implementation**

The control system realized the management of each link in the process of MCG measurement, including movable bed control, acquisition control and data processing control, which was a dialogue application program of MFC developed on the Visual Studio compiling platform.

The interface of the control system (Figure 5) is divided into three sections. (1) The real-time display section shows the MCG and ECG signal. The voltage axis can be automatic or fixed. The status of reading and storing data is also displayed in real time, making it easy to observe if an abnormal situation occurs. (2) The MCG position control section allows manual adjustment of bed movement and automatic positioning to the nine positions corresponding to the chest. Click on the corresponding point and movable bed could automatically bring the human body to the target.
position. (3) The data processing part can obtain the MCG signal of the corresponding point according to the input data file name. Figure 6 shows the program flow chart for the MCG measurement.

Figure 6. Program flow chart for the MCG measurement.

We have used this control system for measurement and obtained the averaged MCG and ECG signal (Figure 7), which shows all units can work in order as the program designed.
Conclusions

We have fabricated a Scanning MCG system in an unshielded environment, which can reduce the cost of the system and be beneficial to the clinical application of MCG measurement. This control system is based on the measurement strategy to achieve the control of each hardware and software units. The software interface has been developed and successfully realized the preliminary measurement function. In the future, we will improve the display and optimize the control logic.

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References


