A Magnetic Field Camera for Real-Time Subsurface Imaging Applications.

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We have constructed an imaging device that can show spatio-temporal distribution of magnetic field in real-time. The device employs 16 units of AMR (anisotropic magneto resistance) 3-axis magnetometers, which are arranged into a 4×4 size sensor-array. All of the magnetic field values measured by the array are collected by a microcontroller, which then preprocess and send the data to a smartphone or a PC using a USB or wireless (bluetooth) channel. An interpolation and display software in the smartphone/PC have also been built to present the field as a larger video on a screen; hence, the device serves as a magnetic field camera. In the experiments, we show that the magnetic-field distorted by objects buried under a surface can be imaged by the proposed device; therefore, we can use it for a real-time subsurface imaging or NDT (non-destructive testing) applications. Camera is an image capturing device. A distinctive feature of a camera is that the entire image (or sequence of images/video) are captured simultaneously, instead of elements-by-elements or pixel-by-pixel. In the latter case, the device will be called a scanner. In the digital camera, usually the captured image is displayed instantly; therefore, we refer the generic name "camera" to refer to a device capable to capture and display the image instantly. Previously, we have constructed a magnetic imaging system utilizing the built-in magnetometer of a smart-phone [1]. To obtain an image representing the distribution of magnetic field intensity, one has to scan the area of interest and then run a reconstruction program to obtain the field values. Therefore, this device is categorized as a (magnetic field) scanner, which will be referred as B-Scanner. The "B" in the names follows the notation of magnetic flux density, which is denoted as B. In this paper, we present a design and realization of a magnetic field camera or the B-Camera. The B-Camera has the capability to capture and display magnetic field distribution of a region instantly. Instead of sequential scanning of a gridded area done in the B-Scanner, we employ an array of magnetometers that measure the field values on a regular grid of the area simultaneously. Then, a reconstruction software will interpolate entire values of in the domain and display the result on the screen instantly. Block diagram and implementation of the device is displayed in Fig.1. The magnetic field camera (MFC) blocks consist of sensor-array part, display, and communication between sensor and the display. In principle, the camera works like the magnetic field scanner, unless the sensors position are fixed at regular grid points/array. The MFC (Magnetic Field Camera) is divided into the following functional blocks: (a) sensor array and multiplexer, (b) microcontroller, (c) communication-1: sensor-array side, (d) communication-2: smartphone side, and (e) computing/interpolator and display. Fig.2 shows the block diagram of the camera and the obtained results. In (a), a coin (made of nickel) is located at the center of the camera array. The display unit, which in this case is a smartphone, shows magnetic field distribution as an image. From the menu, a user can select either the x, y, z, components of the field or its magnitude. The (b) part of the figure shows the image of field distribution when the coin is located at the corner of the array. Both of (a) and (b) consistently shows the magnetic field distribution at the correct place, considering that the user will direct the array downward when performing the imaging.

[1] A. B. Suksmono, D. Danudirdjo, A. D. Setiawan, and D. Rahmawati, "Magnetic subsurface imaging systems in a smartphone based on the built-in magnetometer," IEEE Trans. on Magnetics, Vol.53, No.11, Nov. 2017. [2] M. Volk, S. Whitlock, C. H. Wolff, B. V. Hall, and A. I. Sidorov, "Scanning magnetoresistance microscopy of atom chips," Rev. Sci. Instruments, 79, 023702, 2008.

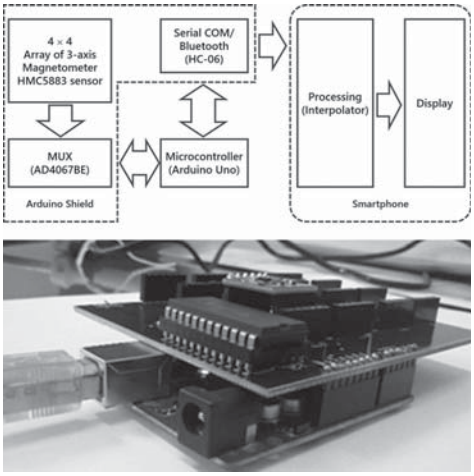

Fig. 1. Block diagram and realization of the magnetic field camera.

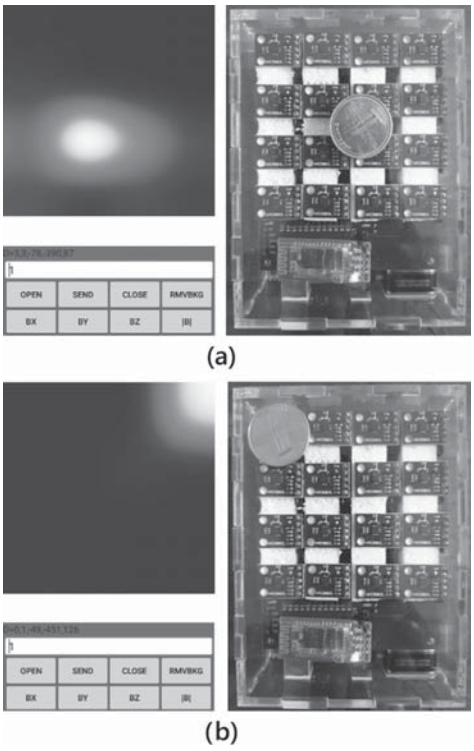

Fig. 2. Magneto-photographs of a coin and its corresponding position at the sensor array. The array is designed to be used downward, so that the left-right position of the image is inverted. The object is a coin (Rp.1000,-), which is made of ferromagnetic material.

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