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Embodiment of Spatially Arterial Pulse Diagnostic Apparatus using Array Multiple Hall Devices

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Abstract

The study relates to achievement and analysis of 3-dimensional spatial pulse wave archived by a spatially arterial pulse diagnostic apparatus (SAPDA), wherein a pulse sensing part array consists of multiple hall devices and is located over a skin contacting part which consists of a magnetic material. When a radially arterial pulse is transferred to the magnetic material, which is contacted skin that results in changes in a magnetic field of the lower part of the pulse sensing part array, the changes in a magnetic field can be detected by the commercial Hall semiconductor device of the pulse sensing part array. Finally, according to development of SAPDA, the 3-dimensionally arterial pulse waveform can be measured noninvasively by detecting the changes of the magnetic field.

Key words : spatially arterial pulse diagnostic apparatus (SAPDA), array multiple hall devices, noninvasive, three-dimensional pulse waveform, magnetic field.

I. INTRODUCTION

Currently, most medical detecting sensors for the pulse are the invasive sensors, which detect the changes in the blood pressure by injecting tubes into the blood vessels[1], or the noninvasive sensors using pressure sensors[2]. The general measuring system of arterial pulse has used pressure and a piezoelectric sensor to obtain a vertical displacement of the artery as time-domain[3-4]. The temporary arterial pulse diagnostic apparatus (TAPDA) has been researched many times due to its noninvasivity and medical automation, and the pulse wave measuring devices are some examples[5-6].

The commercial and medical pulse diagnostic apparatus (PDA) includes a pressure sensing sensor including a silicon layer, which is adhered closely to the upper skin at the radial artery and close up the air layer tight to sense the pressure change of the air layer, which depends on the vibration of a pulse wave[7-8]. Also the conventional PDA includes a silicon gel, which transfers the pressure change of the air layer, and a pressure measuring plate, which measures the pressure changes to be transferred by the silicon gel. The silicon gum, having a hole fit for the pressure sensing part, wrapping the pressure sensing part and being adhered to the front side of the pressure sensing sensor and making the pressure sensing sensor fixed to the skin of the examinee is exist. A fortified plastic plate, being adhered to the back side to the pressure sensing sensor, and transferring the variable pressure from the back side of the pressure sensing sensor to the skin of the examinee is exist[9-10].

The silicon layer and silicon gel, which are in front of the pressure measuring plate, eliminate a cold feeling and unnecessary stimulus of metals, of which the conventional pulse sensing part is comprised. However, the conventional PDA sensor using pressure sensors has the problems that it unnecessarily closes up the air layer tight, transfer the pressure changes indirectly to a pressure measuring plate and is unable to measure the exactly arterial pulse. And it is impossible to

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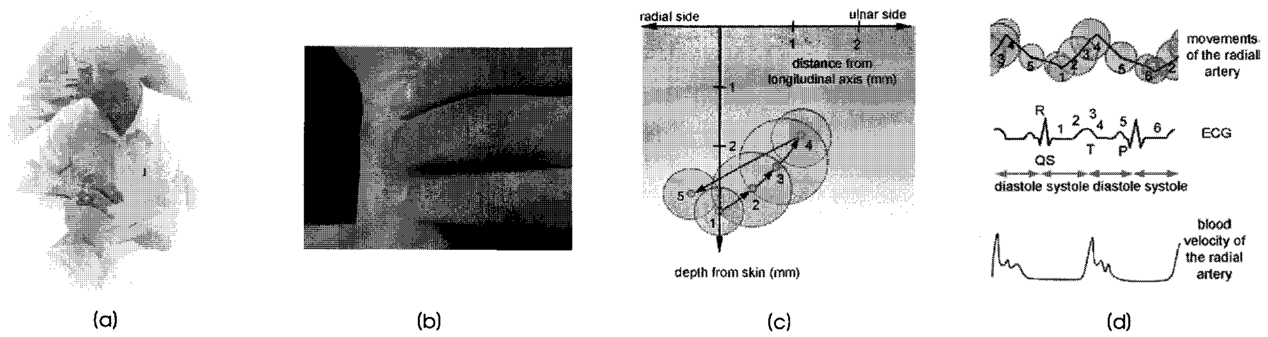


Fig. 1. (a) Traditional pulse diagnostic method, (b) a real photo of wrist and fingers for the three positions ("Chon", "Gwan", and "Chuck"), and (c) movements of the radial artery measured by ultrasonography according to the cardiac cycle. (d) The comparisons of movements of the radial artery, ECG (electrocardiography), and the blood velocity of the radial artery.

search for the location of the pulse depending on each person and measure an exact pulse quickly.

To improve problems which the conventional automatic PDA have, should be to the new mechanical embodiments of the way oriental medical doctors feel th pulse with one pressure sensor. The another conventional PDA regarding the pulse wave measuring device disclosed invention measuring the three regions of "Chon", "Gwan" and "Chuck" simultaneously with three pressure sensors. However, the conventional arts use pressure sensors such as a piezoelectric device, and have the following major problem. It is possible to understand the time characteristics to some extent by measuring the charges in the pulse pressure (wave form) with the pressure sensors, but it is hard to understand the spatial characteristics (three-dimensional configurations) of the pulse such as the depth, the area, the length of the pulse and so on, which have been recognized more important in the traditional pulse diagnosis[10].

To solve above several problems suggested by the commercial PDA, this research show the process of achievement and analysis of 3-dimensional spatial pulse wave archived by a spatially arterial pulse diagnostic apparatus (SAPDA), wherein a pulse sensing part array consists of multiple Hall devices[11] and is located over a skin contacting part which consists of a magnetic material[12-13].

II. MOVEMENTS OF THE RADIAL ARTERY

Fig. 1. (a) and (b) shows typically traditional pulse diagnostic method and a real photo of wrist and fingers for the three positions ("Chon", "Gwan", and "Chuck"), respectively. In general, oriental medical doctors have diagnosed the three pulse locations on the wrist, over the radial artery classified as "Chon", "Gwan" and "Chuck". The "Gwan" is located on the coronal process of the radial artery on the wrist, the "Chon" is located on the spot 1 ~ 1.3 ㎝ from the Gwan toward a palm of the hand, and the "Chuck" is located on the spot 1 ~ 1.3 ㎝ from the Gwan toward an elbow. The doctor places the index, middle and ring fingers on the examinee's the "Chon", "Gwan" and "Chuck" with three different degrees of pressing, that is moderate (the "Bu" state), hand (the "Jung" state), and light (the "Chim" state)[14].

The movements (as shown in Fig. 1(c)) of the radial artery measured by ultrasonography according to the cardiac cycle can be obtained using by a noninvasive medical SAPDA with multiple array sensors. Especially, Fig. 1(d) shows the comparisons of movements of the radial artery, ECG (electrocardiography), and the blood velocity of the radial artery, which have a repeated cyclic period of diastole and systole. The radial artery transverse and vertical movements in the diagnosis area and its expansion, and should be considered in the design a new pulse diagnosis system. Therefore, to obtain the spatial feature of arterial pulse under a contact or noncontact measuring method, and a two-dimensional array (3×15) sensor system using Hall devices.

III. TEMPORAL AND SPATIAL CHARACTERISTICS OF 28 QUALITIES OF THE TRADITIONAL PULSE DIAGNOSIS

To measure the spatial characteristics of the pulse properly, sensors should find out the location of the radial artery properly, and it takes too long to search the locations of the pulse. Because of the nature of the pressure sensors of having a weakness in movement noises, it is impossible to measure pulses with wearing themselves, and this characteristics has an application limit to a portable apparatus. Also, most pressure sensors have been equipped with measuring means of a rigid

Table 1. Temporal and spatial characteristics of 28 qualities of the traditional pulse diagnosis. Only 7 qualities for two boxes marked by thick solid lines, related with the time characteristics can be understood by the conventional arts. The remainders having 21 qualities should be gained by the SAPDA.

Conventional pressure sensor can measure only these 7 qualities.

	Spatial Characteristics								Time Characteristics				
Pulse qualities	Strength	Palpating location Shallow deep very deep			Width Wide narrow		Effective length long short		Period long short no beat period			Slowness of up and down Slow fast	
floating pulse		○	○	○									
deep pulse		◌	○	○									
slow pulse									○				
rapid pulse										○			
large pulse					○								
short pulse						○							
long pulse							○						
short pulse with short extent								○					
slippery pulse													
uneven pulse													
abrupt pulse												○	
knotted pulse										○	○		○
regularly intermittent pulse									○		○		
moderate pulse											○		
full pulse	●				○								
faint pulse	•					○							
weak pulse		◌	•	•		○							
solid pulse	●												
deficient pulse	•										○		
tympanic pulse		●	•	•									
firm pulse		◌	●	●									
tremulous pulse								○		○		○	
hidden pulse		◌	◌	○									
scattered pulse		⊙	◌	◌									
hollow pulse		○	◌	◌									
soft pulse		•	◌	◌		○							
taut pulse													
tense pulse	●												

● strong • weak ◌ absence ○ presence

body and applied pressure on measurement points of a pulse with pains.

Accordingly, as shown in Table 1, only 7 qualities, those are related with the time characteristics, in words, slow pulse, rapid pulse, slippery pulse, uneven pulse, abrupt pulse, knotted pulse, and regularly intermittent pulse, can be understood by the conventional arts among 28 qualities that have been used in traditional pulse diagnosis. Therefore, there has been a limitation on replacing the traditional pulse diagnosis by examiners with new mechanical PDA. Products using the pressure sensors to understand the spatial characteristics of the pulse have been manufactured recently, but there is a limitation on the degree of integrity for pressure sensors. Therefore, there is nothing but to get minimum spatial information about the pulse through an excess interpolation.

IV. DESIGN OF TESTING SAPDA SYSTEM WITH ARRAY MULTIPLE HALL DEVICES

To Solve the problems which the conventional PDA sensors have, our SAPDA is directed to a detecting sensor using a Hall device. To achieve the objectives of the SAPDA, the detecting senor is characterized by comprising a skin to examine the pulse. This system is composed of pulse sensing part, skin contacting part and spatial part. A pulse sensing part, located some distance over the skin contacting part and formed as an array type with at least one Hall device, and other part, a spatial part is located between the skin contacting part and the pulse sensing part, as shown in Fig. 2.

Fig. 2(a) shows the schematic of a cross section of one embodiment of SAPDA sensing part with array Hall devices and 3-dimensional image treatment system. The sensing part of SAPDA is composed of 15 arrays of the A3516 model Hall sensor and the cylindrical type permanent magnets having a size of 1.5 mm dia.×1 mm thick. The flexible spacer between the sensors and the magnets can control the applied pressure of the arterial tube as the doctors' three fingers press the arterial tube. So to realize the ideal pulse diagnosis system it is necessary for the system to have a device to apply certain pressure on the sensors, and both the pressure applied by the device and the pressure obtained from the artery should be recorded. The distance between the elements of an array is

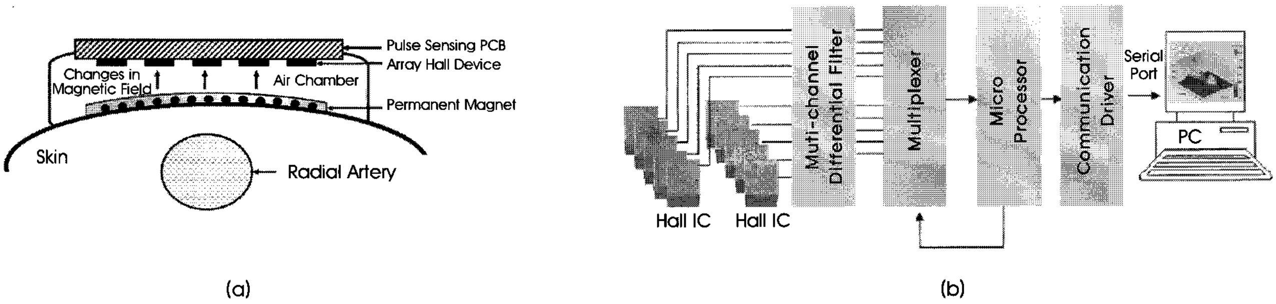


Fig. 2. Schematic of (a) a cross section of one embodiment of SAPDA sensing part and (b) a functional block diagram showing a detected signal treatment hardware which is built in a radial artery 3-dimensional and spatial pulse sensing part.

about 2 mm, and all the cylindrical magnets have an intensity of 100 Oe. The areas of active Hall devices were 0.3×0.3 mm^2 in size, and the linear magnetic sensitivities 2.5 mV/Oe in the region between 0 Oe and 50 Oe. And the temperature range is -40°C to +150°C.

Also, Fig. 2(b) shows schematic of a functional block diagram showing a detected signal treatment hardware which is built in a radial artery 3-dimensional and spatial pulse sensing part. The pulse sensing part further comprises a multiplexer which receives multi signals from the multi channel voltage detecting circuit and selects one signal; a microprocessor which controls the multiplexer in such a way that the microprocessor receives each signal from the multiplexer and makes it a packet with a predetermined resolution and transfers it; and a communication driver which transfers the packet digital signal input by the microprocessor to an outer image processor in a single body. The successive pulse detection system, which is composed of a Hall sensor with signal preamplifiers, a filter, an A/D converter, and imaging process was developed.

On the other hand, by varying the contact pressure height of a permanent magnet on the skin, a new method of characterizing the spatial pulse wave based on the degree of floating, the width, and the depth was introduced. These, unlike the traditional pulse diagnosis, do not involve the analysis of diastolic blood pressure and pulse wave velocity.

V. MEASUREMENT OF PULSE WAVEFORM USING SAPDA SYSTEM

Fig. 3(a) and (b) show the results of the simulation of the magnetic field distribution for the permanent magnet using the finite element method (FEM). Especially, Fig. 3(a) shows two-dimensional distribution of the magnetic field for magnet array in a sensing surface. It is corresponded with the distribution of height displacement slightly changed by arterial pulse fluctuation. To analyze the magnetic field distribution of special wave form, the FEM simulation for the

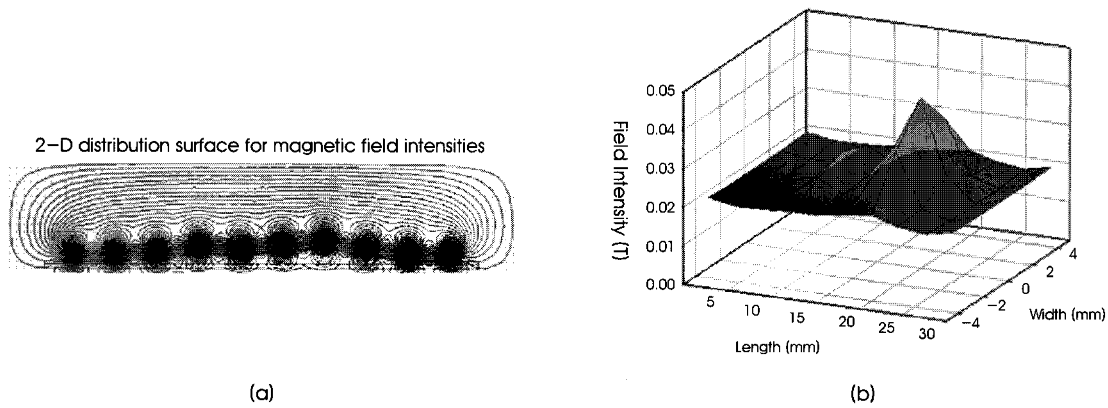


Fig. 3. (a) Two-dimensional magnetic field distribution for a permanent magnet array simulated using the finite element method (FEM). It is corresponded with the distribution of height displacement slightly changed by arterial pulse fluctuation. (b) Characterizing three-dimensional pulse wave based on the degree of floating, the width, and the depth was simulated when the magnetic field was 0.05 T.

array detection system was done. By varying the contact pressure and so the height of a permanent magnet on the skin, a method of characterizing the spatial pulse wave based on the degree of floating, the width, and the depth was introduced as shown in Fig. 3(b) when the magnetic field was 0.05 T. It is expected that not only the blood pressure and velocity of radial artery in Fig. 1(d) can be measured, but also the three dimensional spatial imaging graphics of pulse wave can be obtained by SAPDA.

When a pressure controlling apparatus is adhered to the pressure chamber, it is possible to get pulse qualities easily at the state of “Bu”, “Jung”, and “Chim” of the traditional pulse diagnosis. However, to show the function of the pressure controlling apparatus properly, it is necessary to embody the detecting sensor according to the SAPDA into a wrist watch or a bracelet and transfer the increased pressure to the skin contacting part intact when pressure of the pressure chamber is increased.

We measured signals at the “Chon”. “Gwan”. and “Chuck” region, as shown in Fig. 4(a) using the testing product of SAPDA system, passed signals through the voltage detecting hard ware system as shown in Fig 2(b). made a differential input, an automatic zero set, a noise filtering, a high power gain and output attenuation, output them with 12 bit resolution at 30 FPS (frame/s), RS232C, simulated the result with a predetermined computer processing, and obtained three dimensional image of Fig. 4(b). By the computer processed 3-dimensional image of signals detected by SAPDA, wherein is marked one point pulse to analyze the temporal pulse wave, we can select it. Fig. 4(c) show an example of measuring time (second) versus temporally typical signal of one point pulse obtained from the analysis for an arbitrary 3-dimensional pulse image of one position of small size permanent magnet.

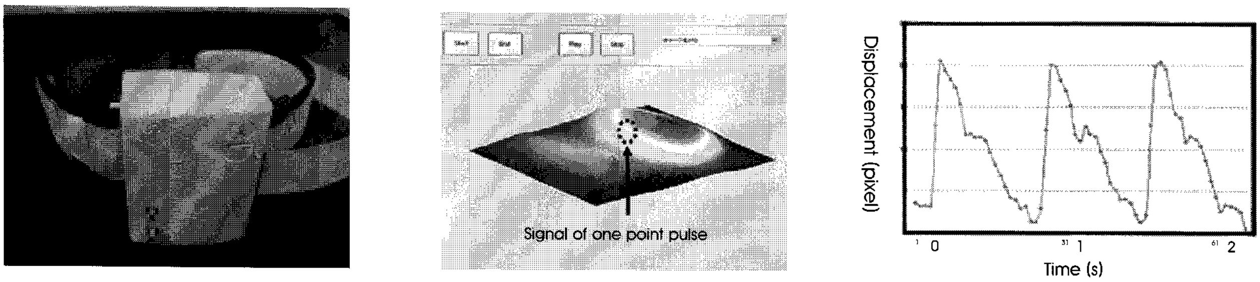
So far, the preferable embodiments of the SAPDA have been described herein, but it will be evident that the SAPDA cannot be defined only by the described embodiments herein, and it will be understood that the SAPDA herein described are generally applicable and executed as various modified embodiments by those skilled in the art, For example. materials and numerical values for a skin contacting part, a pulse sensing part and a spatial part can be various within the technical thought of the SAPDA. Also, Fig. 4(c) shows the signal of one point obtained by the analysis of composition of color 3-dimensional images of testing product of SAPDA. The spatial change of the pulse height in arterial pulse incurred one permanent magnet within 1 mm. We confirmed that one example of measuring pulse signal was reproducible and provided many information for oriental medical diagnosis.

The results of this study were the first reported as regards the advanced use of a commercially available device for the three-dimensionally wearable pulse diagnostic apparatus. To resolve the subtle and subconscious arterial pulse, a more controlled study should be conducted and the real spatial data obtained through future research and development.

This research related to a noninvasive medical pulsimeter sensor using Hall devices. By forming a pulse-sensing part array with a Hall device as a magnetic sensor, over the skin contacting part which consisted of magnetic material, the pulsimeter increased the integrity of sensors, enabled to understand the spatial characteristics of pulse which cannot be determined by the conventional sensors, minimized the time for searching the pulse, and was applicable widely to portable PDA and the likes.

Ⅵ. CONCLUSIONS

The study relates to a noninvasive medical SAPDA using a Hall device. By forming a pulse sensing part array with a Hall device as a magnetic sensor, over the skin contacting part which consists of a magnetic material, our SAPDA increases



(a) (b) (c)

Fig. 4. (a) One photo of the real testing product of SAPDA, (b) the computer processed 3-dimensional image of signals detected by SAPDA, wherein is marked one point pulse to obtain the temporal pulse wave. (c) Example of measuring time (second) versus temporally typical signal of one point pulse obtained from the analysis for an arbitrary 3-dimensional pulse image of one position of small size permanent magnet.

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