Analysis of finger plethysmogram using the Self-Organizing Map

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Abstract - *Recently, it became very attractive to measure the health degree by the pulse wave measuring method. Thereby, we can analyze easily the degree of arteriosclerosis, and the vein age by the subject's pulse sometimes without visiting medical doctors. Already, we proposed the system using the Self-Organizing Map (SOM) for finding the health and the fatigue degree where the measuring time is very short. In this report, we propose the technology for raising the analysis accuracy from the statistics distribution obtained from the feature of the pulse wave.*

Key words - SOM (Self-Organizing Map), plethysmogram

1 The background of the study

In a healthy patient, blood vessels perform important tasks in the body, circulating oxygen and nutrients through the body while retaining elasticity and e xibility in order to sustain variations in blood pressure. But, for a patient with certain risk factors, for example, smoking, obesity, stress, life style related diseases and so on, arteriosclerosis can proceed, leading to deadly acute vascular dieases such as "Hemorrhagic Brain Infarct" and "Hypertensive Cerebral Hemorrhage". Since there are no clear symptoms that can be monitored to indicate imminent risk of these conditions, patients with these risk factors must live in constant fear of sudden onset. In order to prevent vascular disease, daily monitoring is important, but, most of metrical systems of vascular health are too large and expenseive and require a doctor to operate, meaning it is not practical for daily monitoring. In this study, we report on the development of technology to assist the attending physician in diagnosis of the patients condition and sharply reducing patient stress by providing accurate information about the state of the blood vessels. We have developed a compact, fast and easy to use device that measures "Fingertip Acceleration Pulse Wave" and classi es the results using Self-Organizing Maps (SOM) [1] reducing the need for complex data processing. Using this technology, vascular condition can be ascertained at home without the assistance of a physician.

2 De nition of a Pulse Wave

The blood moves from the heart to the periphery through the various blood vessels. This o w is not constant, but moves in pulses which are modi ed by various physiologic conditions, including the physical properties of the arteries. By using our methods to analyze the pulse wave, information about the status of the arteries can be obtained easily in only a minute, simply by placing one's ngertip on the sensor.

Figure 1: Fingertip pulse wave. (a) is Plethysmogram, (b) is a velocity pulse wave obtained by primarily differentiating the (a) Plethysmogram, and (c) is an acceleration pulse wave obtained by secondarily differentiating the (a) Plethysmogram.

The blood vessel responds to the pressure pulse by changing its diameter. By graphing the vessels diameter over time, the resulting "wave form" is called a "Plethysmogram". This "Plethysmogram" has some problems, for example, "Basal Line" isn't stable and uctuates easily, and the undulation of the "Wave Form" is not clear, making it difficult to evaluate the "In e xion Point". In order to solve this problem, a new method to analyse the Plethysmogram "Wave Form" was proposed. In recent years, "The acceleration pulse wave" obtained by secondarily differentiating the Plethysmogram was often used for the analysis as reported in [2]."Plethysmogram" graphing the "change in blood vessel volume" is shown in Fig.1 (a). The velocity pulse wave in Fig.1 (b) is obtained from the Plethysmogram differentiation. The acceleration pulse wave in Fig.1 (c) is obtained by differentiating the velocity pulse wave Fig.1 (b). The Acceleration Pulse Wave's distinctive waveform now contains information in the peaks and troughs that can easily be analyzed to decipher the status of the blood vessel. Currently physicians use the Acceleration Pulse Wave's wave form for diagnosis which is computed by comparing the relative time between certain in e xion points and referring to a database of vascular aging (Fig.2).

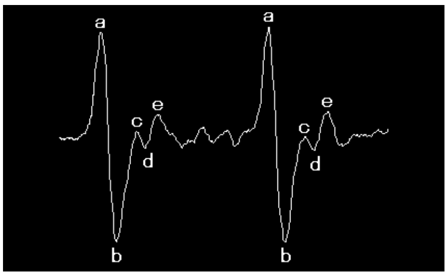

Figure 2: The in ection point of the acceleration pulse wave. Using these in ection points of a, b, c, d and e in the gure, the traditional vascular aging can be calculated.

3 A New Pulse Wave Classification Technique

3.1 The Acceleration Pulse Wave data

For this analysis, we used data from 279 patients obtained at the Hyogo Prefectural Hospital. The doctor adds labels to the waveform and then classifies them into seven groups(A-G) according to the Sano Method [2] (Fig.3). In a healthy patient, the b inflexion point is the lowest value in the acceleration pulse wave as in type A (see Fig.3). On the other hand, as the patient's vessel condition worsens, the d inflexion point falls lower than b, [2, 3] . In addition, the wave amplitude decreases as the arterial walls harden.

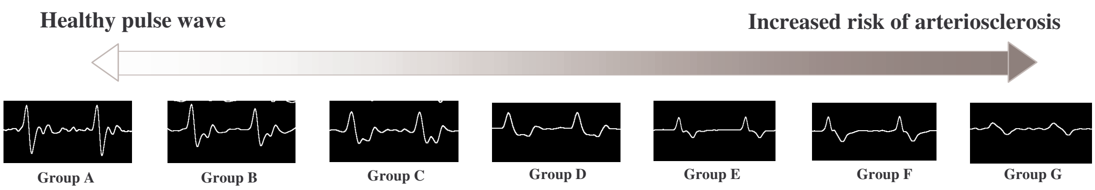

Figure 3: The classification of the acceleration pulse wave by the Sano method.

The pulse wave diagnostic system which is marketed at present is estimating a measurement of the arteriosclerosis degree in the height from the average horizontal axis of the inflection points a, b, c, d, and e of Fig.2. We analyzed more than one pulse wave which were obtained in the measurement. The whole corrugation to a-e of each pulse wave was classified with SOM. By this way, the automation of the classification into the A-G pulse waves of Fig.3 which the medical doctor diagnosed respectively was carried out.

3.2 The wave form characteristics

In order to gauge the degree of arteriolosclerosis, we first examine the local minimum of the acceleration pulse wave. One can easily see the progression from healthy patients where inflexion point b is a local minima, to advanced stages of arteriolosclerosis where inflexion point d is the local minima. Therefore, this time, the rate where a time interval with the wave amplitude from the highest point to the minimum point was occupied in 1 period was carefully analyzed. In this study, we added an additional analysis method by comparing the time interval from the local maxima to the local minima relative to the wave period interval. That is, as the local minima progresses from b in healthy vessels to d in arterial disease, the relative time intervals between local minima and maxima should lengthen relative to the pulse period. We have therefore introduced an additional rate factor in the analysis method in order to increase the accuracy of the diagnosis. The rate factor (Rate) is defined according to one period according the equation and graph below (Fig.4):

$$Rate = \frac{\Delta T}{T} \tag{1}$$

3.3 Statistical Distribution of the Rate

The analysis was carried out using the Rate which was described in 3.2 . The distribution of the Rate was shown in Fig.5 . The transverse is the value of the Rate in the interval with 1 period, taking 0 -

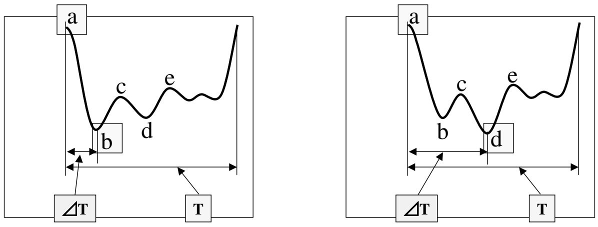

Figure 4: The rate factor "Rate" with 1 period can be calculated using the above de nition in the gure.

1 value. On the other hand, the vertical axis is the number of the pulse waves which were classi ed there. This distribution was carefully examined. There was some exception, too, however, a ne pulse wave was classi ed into the left distribution in equal to or greater than 90 percent accuracy. On the other hand, that the pulse wave which has suspicion of arteriosclerosis was classi ed into the right distribution was con rmed. Compared to previous analytical methods using only the position of points b and d, our current analysis including the parametrical rate parameter, which was sorted into 2 classes forming a SOM for each class, resulted in an accuracy score of greater than 90 percent.

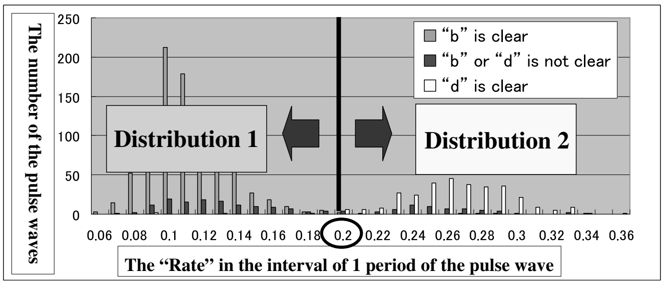

Figure 5: The distribution of the Rate from the 279 examinees.

3.4 Preprocessing

For each patient examined, the local maxima, point a was de ned at the starting point of one period. Next, the amplitude for one period was normalized to a scale from 0 to 1. This normalized single period is divided into 120 units on the time scale as shown in Fig.6.

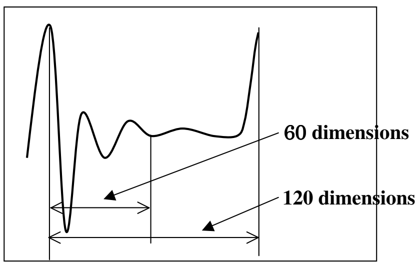

Figure 6: The setting of the number of the dimensions for SOM.

It now becomes much easier for the attending physician to interpret this data up to point e. In order to simplify processing we chose to look only at the rst 60 units to construct the SOM. These 60 units contain the e point. In this analysis, we chose 0.2 as the point of separation for the 2 groups as shown in Fig.5. Therefore, the case to be contained in the left distribution of the Rate at less than 0.2 was classi ed as the distribution 1. Then, the case to be contained in the right distribution at equal to or more than 0.2 was classi ed as the distribution 2. Two SOM mappings were constructed in these two distributions. Then, each of the persons of the healthy pulse wave and the pulse wave which has suspicion of arteriosclerosis were examined with SOM to classify into groups and attempt to raise the accuracy of diagnosis.

3.5 Learning conditions

Pulse wave SOM mapping was constructed using the data from the pre-processing step. Finally, in the conditions of tables 1 and 2, SOM was carried out. A pulse wave with 5 periods per examinee was used. Therefore, it became an examinee number of people times 5 periods amount of data. Therefore, the mapping size which is bigger than the previous case was chosen.

Table 1: Learning condition (for distribution 1)

Initial Rough Learning		Following detailed Learning	
Learning Times	3300	*Learning Times*	33000
Learning Factor	0.9	*Learning Factor*	0.01
Neighborhood Radius	30	*Neighborhood Radius*	1
Map Size	60×40	*Map Size*	60×40
Neighborhood Function	gaussian	*Neighborhood Function*	gaussian

Table 2: Learning condition (for distribution 2)

Initial Rough Learning		Following detailed Learning	
Learning Times	1200	*Learning Times*	12000
Learning Factor	0.9	*Learning Factor*	0.01
Neighborhood Radius	30	*Neighborhood Radius*	1
Map Size	60×40	*Map Size*	60×40
Neighborhood Function	gaussian	*Neighborhood Function*	gaussian

This time, 2 step learning was carried out when the pulse wave SOM mapping was made. The reason is considered in the following reference [1] .

3.6 The SOM mapping which is originated from the distribution

The SOM mapping which was made in the conditions of 3.5 is shown in Fig.8 , where (a) is good, (b) is becoming bad and (c) is very unhealthy in Fig.7. Thus these 3 pattern examples are shown in this gure. Each position with 5 periods of these people is scattered in each area as shown in Fig.8. By this way, using SOM, it became possible to do the wave form classi cation of the acceleration pulse wave very correctly.

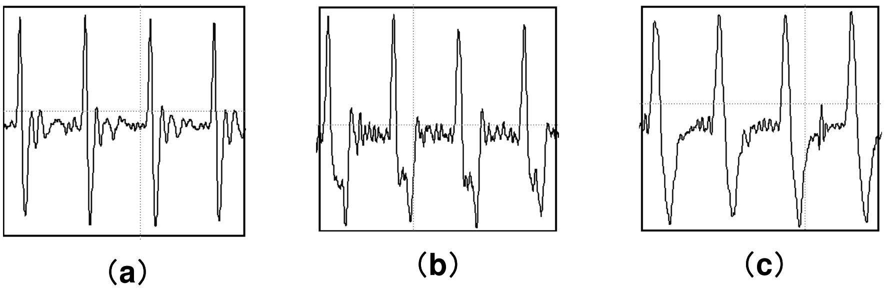

Figure 7: The 3 pattern examples where (a) is good (healthy) pulse wave, (b) is becoming bad and (c) is very unhealthy pulse wave.

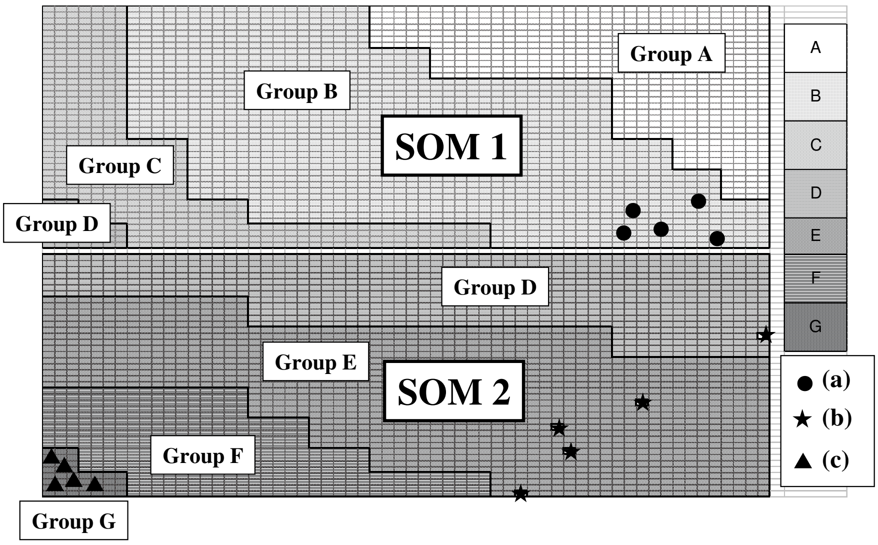

Figure 8: The SOM mapping of the acceleration pulse wave pattern. Each 5 periods of (a), (b) and (c) pulse wave patterns in the Fig.7 are scattered in B, E and G regions, respectively in the gure.

4 Conclusion

This time, the interval from the a point with the maximum wave amplitude of the pulse wave to the minimum b, and d point was carefully taken into consideration. As a result, the distribution which has a characteristic according to the value with rate was observed. Pulse wave SOM mapping was carried out in two distributions. The one of the possibility which improves accuracy over previous methods [4] was so far indicated. Since the whole pattern-of-pulse-waves were classi ed with SOM, the precision improved than the conventional analysis systems which are analyzed only by the a-e points of Fig.2. Also, the estimation of the arteriosclerosis degree became more accurate because a present concept with rate (described in 3.2) was introduced and was used for the classi cation by SOM. For future work, it is necessary to confirm whether or not it is possible to classify these mappings successfully with a larger volume of data.

References

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