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Evaluation of Mental Stress by Analyzing Accelerated Plethysmogram Applied Chaos Theory and Examination of Welfare Space Installed User's Vital Sign

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Abstract: Welfare environment is considered special care such as support to stand up, sit up, walk, take a medicine, etc. Therefore, it is usefulness that the welfare environment support customer by service robot and consider its mind. A analyze brain waves is a kind of mind understanding. However, big equipment is needed for accuracy. In this paper, authors research a possibility of diagnosis of stress by accelerated plethysmogram applied the criterion which combine two evaluation based on chaos theory; trajectory parallel measure method and size of neighborhood space in chaos attractor. And, it calculates time-series data of accelerated plethysmogram measured from forty-tester using proposed evaluations. The authors examine the result of its application to diagnose of stress. Finally, the authors examine that customer's vital information is usefulness to control a service robot and an environment of room based on an ambient Intelligence.

1. INTRODUCTION

Recently, it is becoming easy to introduce support machines and monitors in a room and out of doors, because robot technology has made remarkable advance and the cost has decreased. Under this situation, implementation of the environmental system that support human with robot is advanced. The advance of environmental system must be usefulness for a senior and people with disabilities. The welfare environment is considered special care such as support to stand up, sit up, walk, take a medicine, etc. The introduction of robot will be useful, because these supports are hard. Already, an easy interface have been researched and developed for supporting by robot. On the other hand, it is important to take a health care: sick, pain, mental stress, etc. A physical condition investigates from a secretion, activity of brain, heart, blood, etc. A relatively easy measurement is a plethysmogram of the fingertip or earlobe for reason of low restriction.

In this paper, the authors research a possibility of diagnosis of stress by accelerated plethysmogram applied the criterion which combine two evaluations based on chaos theory. And, it calculates time-series data of accelerated plethysmogram measured from forty-tester using the proposed evaluations. The authors examine the result by using its application to diagnose of stress. Finally, the authors examine that customer's vital information is usefulness to control a service robot and an environment of room based on an ambient Intelligence.

2. VITAL SIGNS

Vital Signs are the sign which shows life support. The signs show four items: body temperature, pulse rate (or heart rate), blood pressure, and respiratory rate. Recently, consciousness is included too.

2.1 Pulse Waves and Accelerated Plethysmogram

It is able to precisely detect changes in circulation dynamics by an easy measurement of the fingertip and has recently been the focus of attention again, as it can easily measure the degree of human arteriosclerosis. However, visual changes in pulse wave patterns along a time series do give medical practitioners precise information about the state of a disease. Medical practitioners are able to diagnose changes in pulse wave patterns along a time-series from their experience of pulse palpation and visual examination, e. g., the pulse waves of the healthy subject can be said to be active and rather free, those of the patient with influenza, tense and simple. In the same way, doctors of Chinese medicine decide on their method of treatment according to the state of the disease by checking a patient's wrist pulse, knowing that the pulse of a healthy patient is mild while abnormal pulse waves are tense and floating.

Accelerated plethysmogram is second derivative of photoplethysmogram. The measurement method become to stabilize basic level and to emphasize a change of trend.

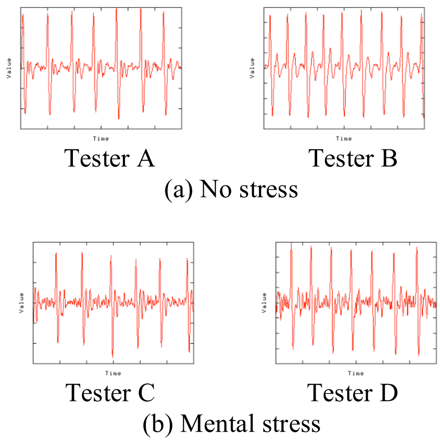
2.2 Time Series of Accelerated Plethysmogram

The authors are prepared the time series data of accelerated plethysmogram measured 20 persons with no stress and 20 persons with mental stress. The 20 persons with mental stress are by a self-return. The condition of measurement describe as table 1.

Table 1. Conditions of measurement

Item	Specifications
Sampling rate	200Hz
Measurement time	6 second
Resolution of AD converter	12 bit

Fig. 1 shows part of them. In general, the Fourier analysis is employed to detect characteristic frequencies. The results obtained by the Fourier analysis are shown in fig. 2. Peek in high frequency is to effect by digital filter. It shows that the feature frequency do not relate for diagnosis of mental stress.



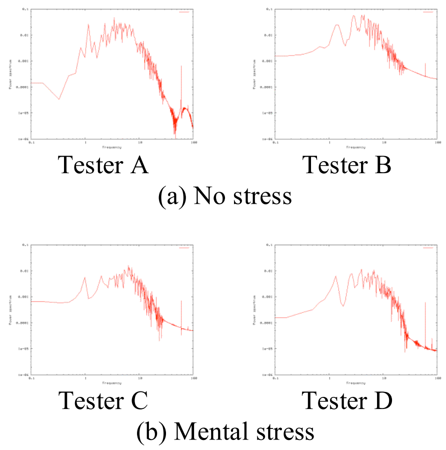
Tester A Tester B

(a) No stress

Tester C Tester D

(b) Mental stress

Fig. 1. Time series data measuring accelerated plethysmogram



Tester A Tester B

(a) No stress

Tester C Tester D

(b) Mental stress

Fig. 2. Power spectrum of the measured accelerated plethysmogram

3. EVALUATION METHOD APPLIED CHAOS ANALYSIS

Chaos is a complex behavior generating relatively simple rule. We had thought to be useless for reason that the chaotic dynamics cannot be modeling mathematically.

3.1 Chaos Theory

Proposition of Takens's embedding theory has been applied chaos theory in many fields. When the behavior of a time series is chaos, it can be assumed that it follows a certain deterministic law. Takens' proposed a theorem to obtain topological information of the determinism. Concretely, when a time series yt is measured from a system, an attractor is reconstructed from yt using delay coordinate. The attractor is the set of embedding vectors. The embedding vector Xt is obtained as :

$$X_t = (\, y_t,\ y_{t-\tau},\ \ldots,\ y_{t-(n-1)\,\tau}\,) \qquad (1)$$

where n is embedding dimension and τ is delay time. The image of process shows in fig. 3. When the embedding operation is repeated on a number of observed data, a smooth manifold consisting of a number of data vectors can be composed in the n-dimensional phase space.

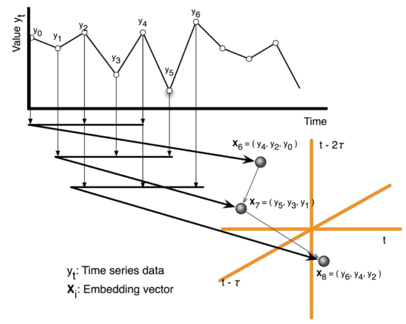
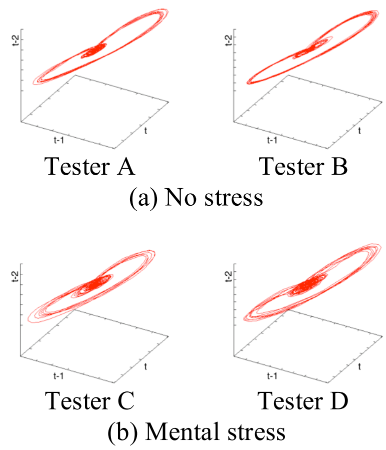


Fig. 3. Reconstruct time-series data in n-dimensional state space, based on Takens's theory.

3.2 Evaluation Method for Mental Stress

Attractors reconstructed time series data of fig. 1 in 3-dimensions are shown in fig. 4. The attractor seems to like a ring rounding some times and twisting one point. Feature of the attractor of no stress is that outside of trajectory pass same line. The other hand, feature of the attractors of mental stress is that outside of trajectory pass several line, and that the trajectory is a little smooth.



Tester A Tester B

(a) No stress

Tester C Tester D

(b) Mental stress

Fig. 4. Attractors reconstructed time series data of accelerated plethysmogram

As an evaluation of trajectory in attractor, Trajectory parallel measure method (TPM method) based on this concept was proposed and shown useful. Thus, the authors recognize to vary widely at the outside of trajectory and to verify a degree of parallelism from appropriation of TPM.

First, the authors discuss a size of neighborhood space. The neighborhood space is subspace for calculating a degree of parallel on embedding vector $\mathbf{X}_i$ and constructed from embedding vectors $\mathbf{X}_{C_{i,j}}$ nearest to $\mathbf{X}_i$ in terms of Euclidean distance. $C_{i,j}$ is index set of neighborhood vectors. If the trajectory of stress's attractor varies widely, it may be identified difference in size of the neighborhood space. Therefore, the average distance d^r gives as following,

$$d^r = \frac{\frac{1}{N}\sum_i^N d_i}{D_{max}} \tag{2}$$

where the scalar N is total number of embedding vector $\mathbf{X}_i$. And the distance d_i and the attractor's scale D_{max} are

$$d_i = \frac{\sum_j^m \left\| \mathbf{X}_{C_{i,j}} - \mathbf{X}_i \right\|}{m} \tag{3}$$

$$D_{max} = \max(D_{i,j}) \tag{4}$$

where the scalar $D_{i,j}$ is distance between embedding vector $\mathbf{X}_i$ and $\mathbf{X}_j$. And the function max($D_{i,j}$) is to calculate maximum of $D_{i,j}$.

$$D_{i,j} = \left\| \mathbf{X}_i - \mathbf{X}_j \right\| \quad i \neq j \tag{5}$$

Next, the authors discuss a degree of parallelism. The trajectory of mental stress is not smoother than that of no stress, looking at fig. 4. The authors assume that number of tpm_i in low range is more clear difference than average of it. Thus, it counts the number to tpm_i less than threshold f. Then, the ratio h_f of that number to total N is calculated as following:

$$h_f = \frac{\mathrm{count}(\, tpm_k < f \mid k : 0..N)}{N} \tag{6}$$

$$tpm_i = \frac{\sum_j^m \left\| \mathbf{T}_{C_{i,j}} - \mathbf{T}_i \right\|^2}{4m} \tag{7}$$

where $\mathbf{T}_i$ is a unit tangent vector of embedded vector $\mathbf{X}_i$, and count ($tpm_k < f \mid i$:0-n) is count tpm_i less than threshold f.

The authors apply the average distance d^r and the ratio h_f for estimation of the accelerated plethysmogram's attractor.

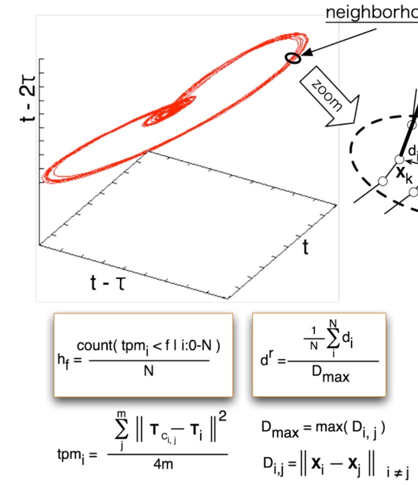


Fig. 5. Evaluations for detecting mental stress

4. EXPERIMENT

Analysis of real data establishes the effectiveness of the proposed method.

4.1 Result by proposed solution

The authors calculate time series data of accelerated plethysmogram measured 20 persons of no stress and 20 persons of mental stress by using the proposed method. The calculated values are plotted in 2-dimensional solution space that the horizontal axis is the average distance dr, and the vertical axis is the ratio hf in neighborhood space. The result shows in fig. 6. In fig. 6, it seems that no stress area and mental stress area exist in 2-dimensional solution space.

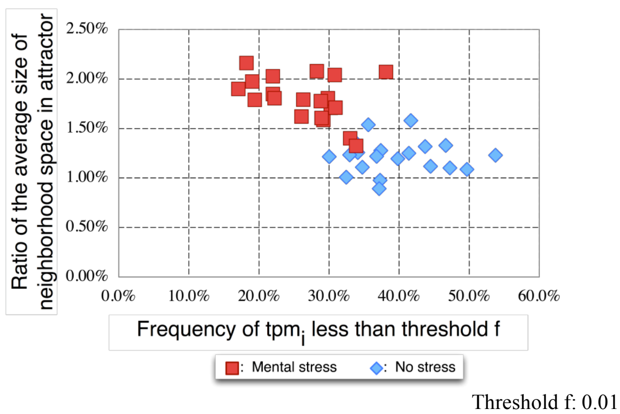
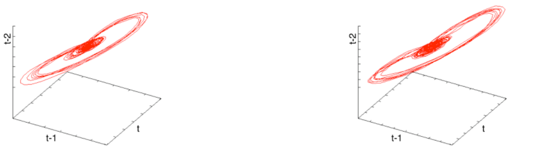


Fig. 6. Attractors of time series data measuring accelerated plethysmogram

4.2 Discussions

The result shows that the present method has highly performance for detecting mental. It is short time for analysis mental condition. The method may distinguish user's mental condition in real time. Two persons with mental stress are included in the no stress area. Two attractors show in fig. 7. The attractors of two persons are very similar to no stress's attractor. There is a possibility that the stress of two persons are lower than their self-diagnosis.



Case 1 (mental stress)   Case 2 (mental stress)

Fig. 7. Similar case to attractor of no stress.

5. EXAMINATION OF APPLICATION BASED ON AMBIENT INTELLIGENCE INCLUDED USER'S VITAL SIGN

The authors assume that a welfare space monitoring vital signs is necessary for a senior whose has illness, handicap, or lose faculty for thought, so the age is more higher. The proposed concept is that the robots assist the customer automatically with diagnosis of which the measured vital sign is analyzed in the ambient intelligence. Fig. 8 shows example of welfare space constructed in combination of monitoring vital condition and supporting senior people by service robot. The welfare space will realize as following:

(1) The ambient intelligence adjusts to the customer's gesture interface, when the ambient intelligence detect that the customer has a irritation or stress.

(2) The service robot comes to the customer with household medicine, when the ambient intelligence detect that the customer get out of condition.

(3) The power assisted handrail robot comes to the customer, when the ambient intelligence detect that the customer of weak legs is going to stand up probably.

The support of standing up in item (3) imagines a robot added self-moving function to Takahashi et al's power assisted handrail.

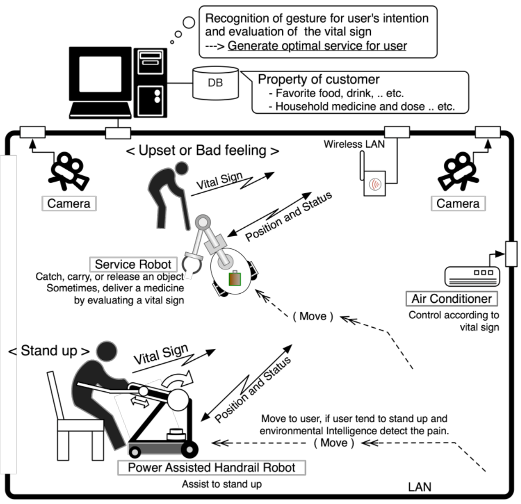


Fig. 8. Image of welfare robot service based on physical condition

6. CONCLUSIONS

This paper proposed the method applied chaos theory for indicating a mental stress quantitatively. And, the experiment confirmed that the proposed method has a high potential for evaluating mental. Finally, the authors described the concept about a welfare environment used vital signs

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