

DATA FLOW MANAGEMENT IN TELEMETRIC BODY AREA NETWORK SYSTEM

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Abstract – It is important to keep our health condition well for independent activities in dairy life. The good health contributes to realize high Quality of Life (QOL). This paper describes the system construction, operation and application of the telemetric wearable sensing network system to monitor vital parameters far from a user. The wearable sensing network is constructed as a Body Area Network (BAN) which take a role of local data management and advising to user. Host System far from the BAN take a role of total monitoring of human and System condition.

Keywords: data management, wireless network, telemetric system

1. INTRODUCTION

Enhancement of QOL is a fundamental aim of human activities in dairy life. There are many kinds of parameter to effect the QOL. The health condition is the most indispensable parameter. Then people hopes to keep good health by walking and physical training. The health condition is monitored mostly in static postures like sitting on chairs and lying on bed indoor. But as 66% of life time in a day is an active time, the health condition should be monitored dynamically in dairy activities.

These days, wearable BAN system is used to monitor several kinds of vital signs like heart rate (HR), body temperature, SpO2, skin resistance and electrocardiogram (ECG) and so on. Using this system, the person monitored can know them by himself. But in case of monitoring of dairy activities of aged people, his health condition is the high concern for the people to care him. On the other hand, in case of monitoring of people in training, his body and health conditions are also the high concern for coaching staff of him.

In this paper, the expansion system of wearable BAN to monitor the health condition and body behaviors at the other place far from subjects is shown. The expansion is realized to attach the telemetry system by using "Cloud" System to wearable BAN. This Telemetric BAN operate not only to monitor the health condition and body behaviors, but also to give advices and information to the user who wears BAN.

2. SYSTEM CONSTRUCTION OF TELEMETRIC BODY AREA NETWORK SYSTEM

2.1. System structure

Fig. 1. shows the system structure of telemetric Body Area Network (TBAN). This system is constructed by 6 wearable sensor nodes (WSN), Hub Node and Host System. Each WSN has some measuring functions. WSN 1 measures HR, body temperature and SpO2. WSN 2 and WSN3 measure acceleration and gyro. WSN 4 and WSN 5 measure the acceleration. WSN 6 measures the acceleration, air temperature and gyro. These 6 WSN work as local node. They use wireless communication; Zigbee. Each WSN has micro controller (PIC) to control sensors and communication units. Basically, each WSN takes roles of sensing, data processing and data transmitting to Hub Node. For example, WSN 4 and WSN 5 estimate walking pitch and posture by the local data processing. Hub Node has two functions; Receiver and Gateway. Receiver section receives and decodes the data sent from WSN. Gateway section takes roles of data fusion processing, data storage, acquisition of GPS information, temporary displaying of data/information, communication to Feedback System for user and data transmitting to Host System by using "Cloud" System. Feedback System is human interface for user who wears BAN. This system is connected with Hub Node by Bluetooth communication device. "Cloud" System is telemetric communication way as a cloud service for connecting Hub Node and Host System. The communication is two way by e-mail or file synchronization.

Host System is the computer far from user who wears BAN. This system receives the data sent from Hub Node and shows the physical behaviors and condition of user. In addition, this system sends the command to Hub Node. This command is to send advices to user and to manage BAN, such communication between BAN and Host System constructs Telemetric Body Area Network System.

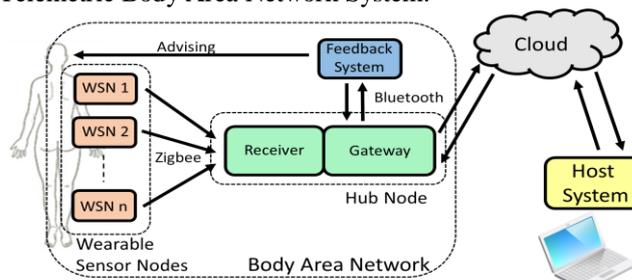


Fig. 1. System structure of TBAN

2.2. Accessibility of “Cloud” System

Fig. 2. is the data flow by “Cloud” System. There are three communication methods to use cloud service. The first way executes reading and writing directly for “Cloud” System. This way writes directly the data which is sent from Hub Node for “Cloud” System, and Host System reads directly that data and receives the data. The second way uses e-mail. This way sends e-mail that includes the data from Hub Node to Host System. The third way uses file synchronization. This way synchronizes the file that creates in BAN between Hub Node and Host System.

In these three way, TBAN uses sending e-mail and file synchronization. There are two reasons using dual way communications. The first reason is a speed improvement of the data communication. The size of communication data is various. Therefore, if the communication method is one way, Host System receives the data deviated timing. If the communication method is dual way, Host System can receive the data constant period keeping decided to one way sends small size files and another way sends big size files. The second reason is risk management. If one communication method cannot send the data caused by device trouble, “Cloud” System can use another communication method and send the same data.

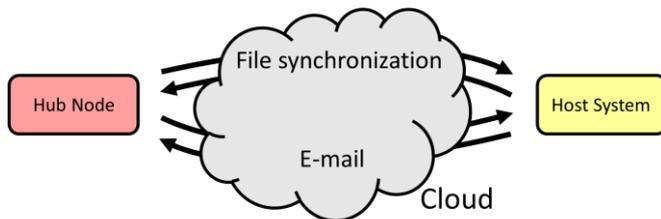


Fig. 2. Data flow by “Cloud” System

2.3. Function of Hub Node

Hub Node is the core in BAN which has MPU/CPU as a center and transmits, receives and processes the data that is sent from BAN. Fig. 3. is the overview of Hub Node.

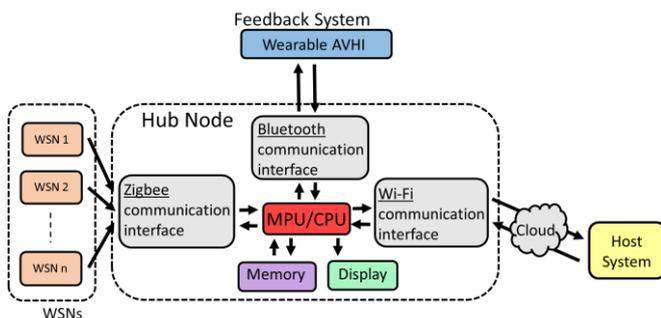


Fig. 3. Overview of Hub Node

The communication between each WSN and Hub Node is Zigbee communication interface. Zigbee is suited the one-to-multi communication method, so it is useful in the communication between plural WSNs and Hub Node. The communication between Feedback System and Hub Node is Bluetooth communication interface. Bluetooth is one-to-one

and interactive communication method, so it is useful in the communication that needs interactive communication between Feedback System and Hub Node. The communication between Host System and Hub Node is Wi-Fi communication interface. Wi-Fi is able to communicate to remote location, so it is useful for the communication between BAN and remote location.

Hub Node uses SP as a telecommunication equipment having MPU/CPU. SP is equipped with the display and the memory. Also Hub Node mounts PIC because of the management of Zigbee. The SP is included in Gateway. The PIC is included in Receiver. Fig. 4. is the construction of Hub Node.

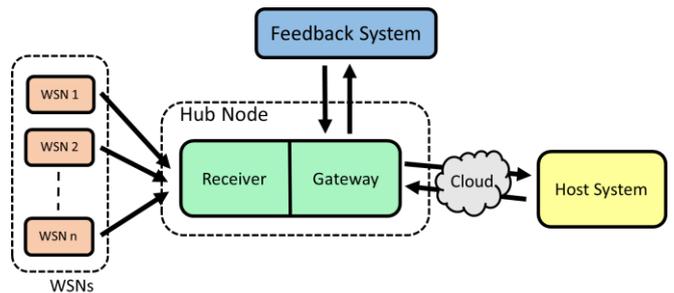


Fig. 4. Construction of Hub Node

Receiver section receives and decodes the data sent from each WSN and sends it to Gateway. Gateway receives the processed data sent from Receiver and sends it to Host System through “Cloud” System. SP in Gateway sends the GPS information using the function of GPS in SP. The communication between PIC and SP is USB interface. SP shows the processed data using display in SP. In addition, SP receives and decodes the command sent from Host System and transmits it to Feedback System. Feedback System shows the context of command.

In these components, Hub Node is an essential existence that locates the center in the data flow and handles the different communications in TBAN.

2.4. Feedback System construction

Feedback System in TBAN is Wearable Audio Video Human Interface (AVHI); head mount display created. Fig. 5. is the construction of Feedback System. Feedback System sends information visually and auditory using AVHI. The functions of AVHI are three ways; taking a picture, playing a sound and displaying the data. The part of displaying data shows text, picture and movie. This system tells the data as a graph and picture to the user who wears BAN using the part of displaying the data. In addition, this system sends the sound advice to user using the part of playing a sound.

Feedback System is easy to tell the advice which is difficult to understand only to see the data using sound and picture to user who wears BAN. That is to say, Feedback System can tell not an obscure advice, but an intuitive advice. Additionally, Feedback System in TBAN can receive the advice without specially motion which is the dairy life style, so this system does not interfere with dairy life.

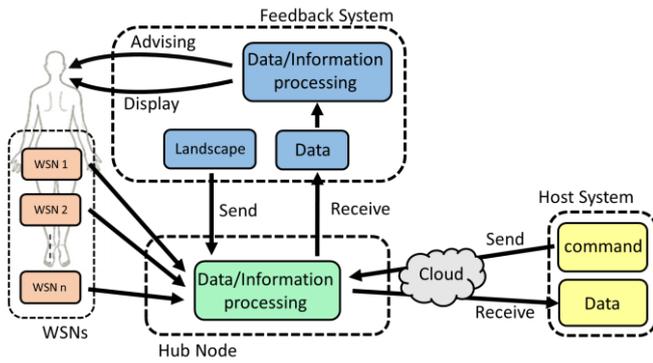


Fig. 5. Construction of Feedback System

3. CONSTRUCTION OF HOST SYSTEM

Fig. 6. is the data flow of Host System. Host System is the computer existing a remote location. First, Host System receives the data from Hub Node through “Cloud” System that as e-mail or file synchronization. Next, Host System takes a role of the data and shows the condition of user. The way to show the condition is plotting out the graph and picture. In addition, this system shows the location information of user by GPS data from Hub Node. If there is a necessity which tells information from Host System, Host System creates the command and sends it to Hub Node through “Cloud” System.

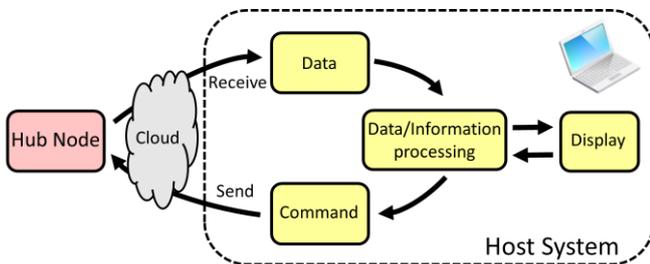


Fig. 6. Data flow of Host System

Host System is a core in TBAN. The first reason, Host System can accumulate enormous data. Using that data, observer of Host System can consider various point of view. In addition, it is easy to compare the current data and the previous data. This is difficult in BAN. The second reason, Host System can process a lot of data in same time. Therefore, the system can communicate to Hub Node asynchronously. The final reason, Host System is constructed by the computer. Following these reasons, Host System is the essential part in TBAN.

4. TASK CLASSIFICATION BETWEEN HUB NODE AND HOST SYSTEM

Both Hub Node and Host System have high spec. MPU/CPU, so TBAN can apply the system smoothly by distributing of roles.

4.1. Role of Hub Node

There are three roles in Hub Node. The first is the real time processing. Hub Node processes various data which is sent from WSN, Feedback System and Host System. If that processing data in Hub Node is slow, the data flow in TBAN is slow and the whole of system becomes hard to use. However, if Host System tries to perform the real time processing, the timing receiving data is slow than Hub Node. So this is the role of Hub Node. The second is the keeping BAN. If Hub Node does not perform as a Node in BAN, the data flow in BAN is stopped. The third is the interchange as transferring data and information. Hub Node exists as a relay point in data flow, so Hub Node carries the data/information interchange.

4.2. Role of Host System

There are three roles in Host System. The first is the controlling data processing. Host System has all data which is sent from BAN, so Host System can process the data controlling using all data. The second is the management of whole system. Host System is out of BAN, therefore Host System can see BAN from outside and this leads to manage the whole system. The third is the data examination using plural component. Host System saves various data which is sent from WSN and Feedback System. Accordingly, Host System can consider the data in different point which is not common view.

5. APPLICATION AS WALKING CARE SYSTEM FOR AGED PEOPLE

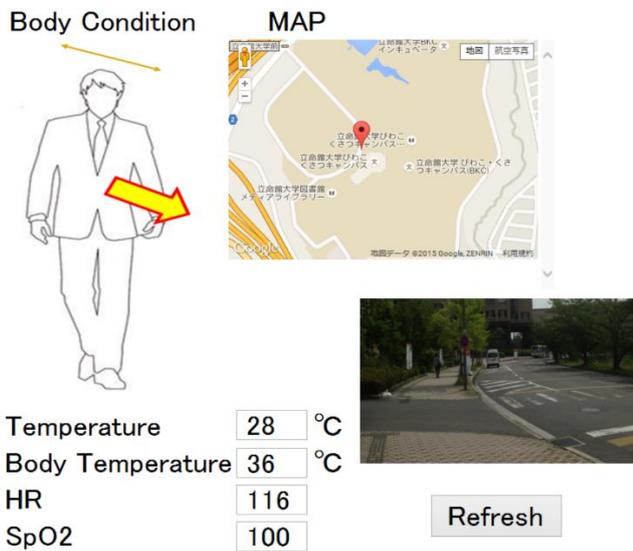
This application is the walking care system for aged people. This application shows the data which is able to see the condition of aged people from BAN and care by these data at Host System. The showing parameters are HR, SpO2, a status of body, current position, view of seeing. In this application, WSN 1, WSN 4, WSN 5, WSN 6, Hub Node and Feedback System are used.

There is a photography one of the functions in AVHI of Feedback System. This application takes a picture using the photography in AVHI and sends the picture to Host System. Host System receives the picture and GPS information from SP. Using these data, Host System shows the condition of user who wears BAN clearly. Accordingly, observer of Host System who exists remote location grasps not only the current position but also the temperature and the condition of the road.

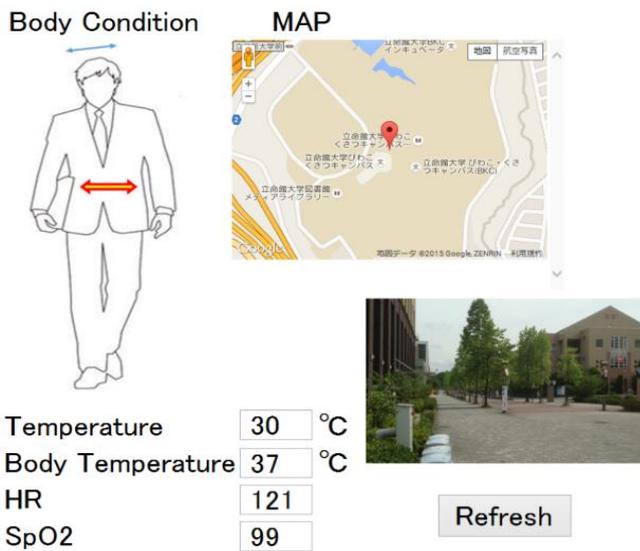
This application essentially does not act the operation, only cares the user. If the abnormal actions (keeping stay same position and so on) are identified, this application demands the more data for BAN and tries to grasp the detailed condition.

Fig. 7. shows walking care by TBAN using this application. This figure shows the body swing and body pose using human silhouette, current position on the map, the view picture from Feedback System and the each parameter by the number. In Fig. 7. (a), the body of user has a large swing and leans to the left. Seeing the view picture, user walks near the road which can guess to go many cars any time, so observer of Host System knows that user has to be careful to walk.

In Fig. 7. (b), the body of user has a small swing and does not have leaning. Seeing the view picture, the walking road is wide, so observer of Host System knows that there is few danger in walking.



(a) Experiment result (case A)



(b) Experiment result (case B)

Fig. 7. Walking care by TBAN

This application can not only keep the autonomous dairy life of aged people but also care them from remote location. To care from a remote location leads getting a sense of security for aged people and also leads staying more actively life. Observer of Host System can know the state of aged people without going to near them, so people can get a sense of security. In addition, if observer of Host System have a computer, they can care aged people anytime and anywhere. Therefore, there is a no obstacle in observer of Host System dairy life.

6. APPLICATION AS HEALTH MONITORING OF BAN SYSTEM

This application conducts the health monitoring of equipment in TBAN. The way to conduct the health monitoring is two ways.

First, each WSN sends the data which is the count of sending data and the working time of WSN. Host System receives these data and checks whether the error exists in the data or not. If the error exists in the data, Host System determines where is happened the error and sends this matter to user through Hub Node using Feedback System. If the working time of WSN is over the fixed time, Host System shows this condition at the same way.

Second, if the acceleration sensor of each WSN measures the decided value in case of sitting, each WSN sends the real data which does not process apart from the common data that is operated. Host System checks the context of these data and judges whether the accident happened in WSN or not. Executing the health monitoring, user who uses TBAN can grasp quickly the error of equipment which is difficult to know.

7. APPLICATION AS JOG EXERCISE MANAGEMENT

7.1. Measurement method

There is an exercise management application in TBAN. This application leads user to the adequate exercise. This application manages the jogging.

This application leads user to the exercise intensity of hopeful by using HR. This application uses voice advice for feedback to the user, and makes them to keep satisfactory exercise.

This application uses Karvonen Formula for deciding the threshold and index of making advice. Relationship of heart rate and exercise intensity is defined by Karvonen Formula. The expression (1) shows Karvonen Formula. In this formula, HRmax means (220 - age), HRmin means the heart rate in normal time and HR means the heart rate in exercise.

$$EI [\%] = (HR - HRmin) / (HRmax - HRmin) \times 100 \quad (1)$$

[Karvonen Formula]

This application uses Karvonen Formula for deciding thresholds of heart rate. In the Karvonen Formula, 40-50 [%] mean Light exercise (walking), 50-60 [%] mean Medium exercise (slow running), 60-85 [%] mean Stressed exercise (hard training) and 85-100 [%] mean Heavy exercise (athlete level). Table 1. shows relation between EI and exercise.

Table 1. Relation between EI and exercise

EI	Exercises
40-50[%]	light exercise (walking)
50-60[%]	medium exercise (slow running)
60-85[%]	stressed exercise (hard training)
85-100[%]	heavy exercise (professional level)

This application decides target heart rate area by Karvonen Formula. For example, if user wants to do stressed exercise, Maximum of target heart rate (HR Top) is the heart rate that corresponds to 85% of EI. In the same way, Minimum of target heart rate (HR Under) is that corresponds to 60% of EI. In order to increase the effectiveness of the application, two thresholds that divide the range between HR Top and HR Under into three parts are set. These two thresholds are named Th1 (lower value) and Th2 (higher value). If the user is 23years old, the heart rate of normal time is 60[bpm] and want to exercise in the intensity between 40% to 60%, target heart rates are 142(HR Top), 114(HR Under), 120(Th1) and 136(Th2). Fig. 8. shows the example of this user.

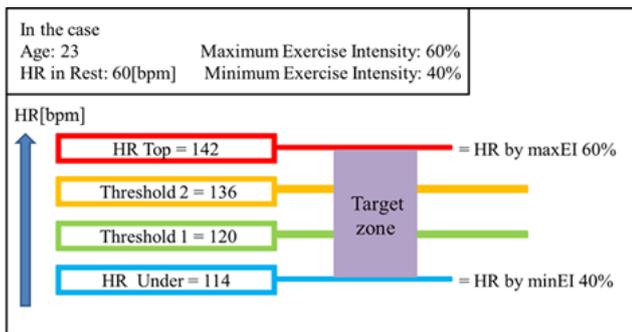


Fig. 8. Thresholds and target zone of HR

Trend means the change of heart rate. Trend and threshold judge kinds of advices. Trends are classified into three parts. These are $[trend \leq 0]$, $[0 < trend < 2]$ and $[2 \leq trend]$. Trend is calculated by measured heart rate once in three seconds. Table 2. (a) shows the method of advice generation by existing range and trend of heart rate. Table 2. (b) shows kinds of sound advice. This system feeds back to the user by six kinds of advice. These function will lead user to proper exercise.

Table 2. Kinds of advice

(a) Judgement of advice

Current HR	Trend of HR	gradient value = 0	0 < gradient value < 2	gradient value ≥ 2
HR < HR Under			1	3
HR Under ≤ HR < Thr 1		2	2	3
Thr 1 ≤ HR < Thr 2		2	3	
Thr 2 ≤ HR < HR Top		2	2	5
HR Top ≤ HR			6	

(b) Sound advice

Advice type	Advices contents	Symbol color (in graphs)
1	Pace up slowly	Orange
2	Keep pace	Yellow
3	Pace down slowly	Light Green
4	Pace down	Green
5	Pace down quickly	Dark Green
6	Stop exercise now, have short rest	Red

After experiment, usefulness of this application is judged. Evaluation method is existence rate in threshold. Existence rate in threshold is existence rate that heart rate is in threshold. If this rate is high, user can exercise in ideal exercise intensity. Existence rate in threshold is measured by formula.

$$\text{Accuracy rate} = \frac{\text{Number of Data of matching HR}}{\text{Number of Data of running term}} * 100 [\%] \quad (2)$$

Usefulness of this application is confirmed by comparison of results of the case of exercise with advice and the case of exercise without advice. If result of exercise with advice is better than result of exercise without advice, this application is judged useful application.

In this method, WSN 1, WSN 6, Hub Node and Feedback System are used. All of these experiments are conducted on treadmill. Time schedule of this experiment consists following schedule. Objective exercise intensity is 50-60% (slow running).

1. Stand statically for 1 min.
2. Jog without advice for 10min.
3. Jog with advice for 10min.
4. Stand statically for 5 min.

7.2. Experiment result

Fig. 9. shows result of subject A in BAN. Obviously, subject A do over exercise at without advice. If subject A keep this exercise, subject A may hurt a part of body. It is very hazardous situation. At exercise without advice, existence rate in threshold is only 3.0%. However, at exercise with advice, existence rate in threshold is 87.0%. Existence rate in threshold increased 84.0%. This application is effective for people doing extreme over exercise like subject A.

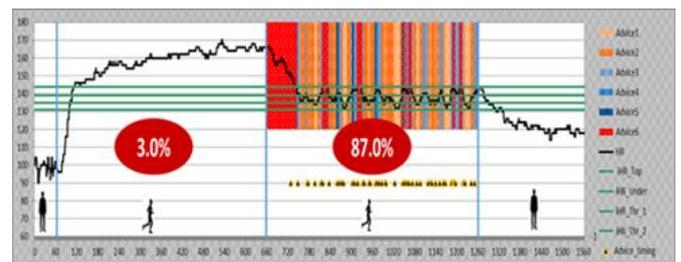


Fig. 9. Result of subject A

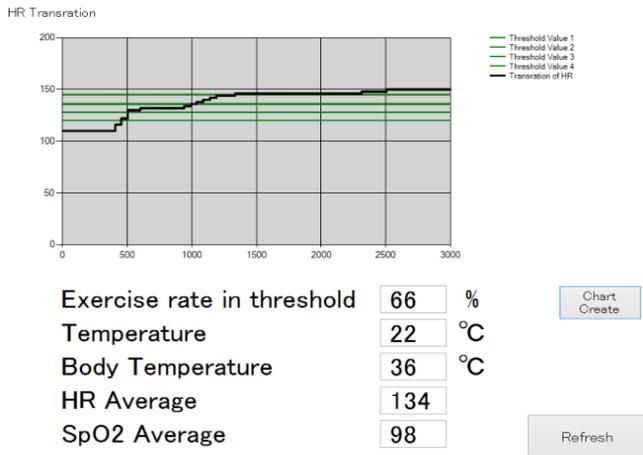
7.3. Measurement by TBAN

In this method, WSN 1, WSN 6, Hub Node, Feedback System and Host System are used. The way to get the experiment data is same as mentioned above and displays the data part of 3 min. in the experiment.

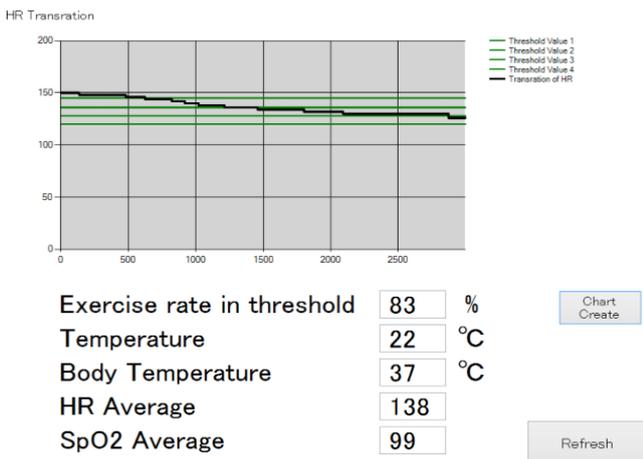
In TBAN, Host System shows not all data but part of data. That data is measured 1 min.. In addition, Host System shows the existence rate in threshold by that data. Besides, Host System shows the average of HR, average of SpO2, temperature and body temperature using that data.

Fig. 10. shows result of subject A in TBAN. Showing the result in Host System, people can know the detailed

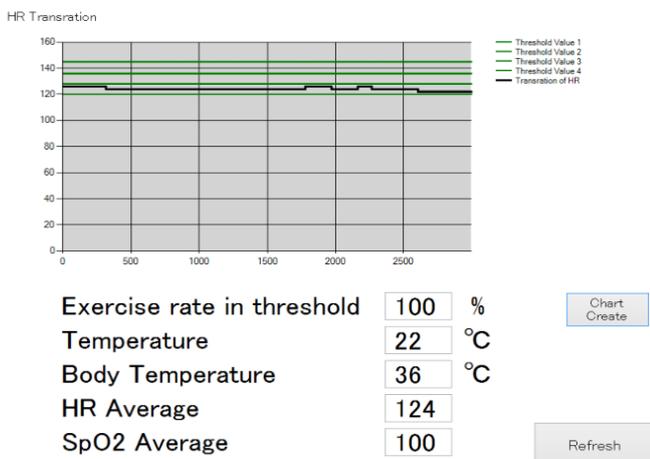
translation of HR. In addition, Host System can show the existence rate in threshold by the part of data which cannot show at last in BAN one after another. Using the display, people can grasp the exercise intensity whether user takes hard exercise which is over expectation and tell the average of existence rate in threshold to user.



(a) First 1 min.



(b) Second 1 min.



(c) Third 1 min.

Fig. 10. Result of subject A in TBAN

7.4. Discussion

The result in BAN, people can total data at last. This is useful in the looking back after finished the exercise. Additionally, the result in BAN can know what kind of advice during the experiment, so user and coach are able to find whether the HR of user tends to rise quickly or down quickly. The result in TBAN, people can see small data one after another. This is useful in the looking back frequently, so people can aware of the user trend. People also can see the past data quickly and compare current data to past data. In Addition, people can use various data in the same time, they are able to be a home doctor.

For athletes, the care from a remote location using this application leads having coach by a coach who exists in a remote location anytime and anywhere. For coaches, they can keep coaching without closing to athlete.

8. CONCLUSION

This Telemetric Body Area Network System contributes to improve QOL of user. The system can collect various body parameters and send these data to a remote location. Using this system, people can prevent physical troubles and care user from Host System. For aged people, this system can care the dairy event and give both observer of Host System and aged people a sense of security. On the other hand, in sports, athlete can receive the advices at all time without coaches.

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