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Simulated Data Extraction on the Heart Rate Variability, Biosignal, Blood Pressure, and Muscle Fatigue Using Biometric Predictive Tools

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ABSTRACT: *In this study, a method to obtain information related to bio-signals through simulation without relying on measurement experiments was used.Data measurement was conducted through research verification using a graphic programming tool without directly going through the experimental measurement equipment.Among the bio-signals for measurement, muscle fatigue, electrocardiogram, blood pressure, electromyogram, grip strength, and skin temperature were selected.Bio-signals were analyzed based on NI's programming tools.By analyzing the waveform of minute changes in heartbeat, the body's autonomic response to stress was visualized and the current state of health and psychophysiological stability could be analyzed.The skin surface temperature sensor can have a fast response rate when the thermistor is exposed and can be used for low thermal mass measurement in situations where flexibility is required.The strain-gauge type based on static contraction can measure the grip pressure and pinch pressure, and it is possible to know the degree of muscle fatigue.ECG sensors measure electrical signals generated during muscle contraction and can be used for 3-lead EKG tracing or surface EMG recordings.Electromyography, which records potential differences due to action potentials generated during muscle contraction, could be used in conjunction with a grip dynamometer or an EKG sensor to measure detailed muscle activity.In future studies, based on the results of this experiment, we will compare the results obtained from the measurement system to improve reliability.*

KEYWORDS –*Bio-instrumentation, Biometric Predictive Tool, Bio-signal, Muscle Fatigue, Electrocardiogram, Electromyogram*

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I. INTROD1UCTION

The bio-signal is a signal measuring the characteristic state of a living organ, and is used for diagnosing a person's health condition. It is possible to measure various bio-signals such as blood pressure and pulse based on electrocardiogram (ECG), electromyogram, and electroencephalogram signals.Measured biometric information is a basic information element that can identify an individual's disease or health condition, and is used as information for personal health management as well as in medical institutions where professional disease treatment and management are performed [1-2].In general, bio-signals are measured during daily life, exercise, or for diagnostic purposes by attaching a sensor to the body, but recently, a method for checking health conditions in real time by attaching a chip to clothes is being developed.MATLAB is used for bio-signal analysis research, and source conversion work is required to apply the algorithm developed with MATLAB to the system. A smart interface has also been developed that can eliminate source conversion work [3].

As the technology of the industrial field has recently been advanced and the distribution cycle of products has been accelerated, the importance of product development, inspection and performance evaluation applied with cutting-edge new technology is increasing. In order to reflect these requirements, it is necessary to measure and analyze various phenomena and physical quantities that occur in actual industrial sites using a computer or embedded system, and implement appropriate control and countermeasures remotely based on this.A programming tool developed primarily for these measurement, analysis and control functions is LabVIEW (Laboratory Virtual Instrument Engineering Workbench) from National Instruments.In addition, not only can it support script languages such as MATLAB, but also mathematical calculations and modeling have become possible with the addition of various mathematical functions [4-5]. In addition, as various hardware solutions related to data acquisition, machine vision, distributed control system, real-time system, automation controller (PAC), RF and wireless system are provided, their utilization is increasing throughout the automation test and industry.

This study aims to verify data prior to designing a biological system from data measured using a measuring instrument, and to predict compatibility with simulation signals such as bio-magnetism and bio-electricity.

II. EXPERIMENTAL METHOD

2.1 Installation of Bio-signal Measuring Tools

Since the biometric system is related to pattern recognition, the method of this experiment was divided into (i) experimental setup, (ii) preprocessing, (iii) feature extraction, and (iv) classification.

A sphygmomanometer sensor is a non-surgical sensor designed to measure human blood pressure. Vibration techniques are used to measure blood pressure during contraction and relaxation of the heart. The sensor consists of a standard adult cuff (27 cm to 39 cm), valve pump and pressure gauge.

A connector allows the use of Vernier analog BTA sensors on NI ELVIS prototype boards.

<Bio-signal logger >

- Acquire signals using the analog input channels of NI hardware (NI ELVIS II or NI data acquisition (DAQ) hardware).
- Save data as TDMS file.

Fig 1 shows the bio-signal logging installation status.

Status : ON

All Channels

Device: Dev4 (NI ELVIS II)

Figure 1. Bio-signal logger display

2.2 Heart Rate Variability (HRV) Measurement Using a Hand Grip Pacemaker

The human body's autonomic response to stress was visualized by waveform analysis of heart rate variability (HRV), and the current state of health and psychophysiological stability were analyzed.

For heart rate measurement, NI myDAQ hardware other than a hand-grip heart rate monitor provided by Vernier was used.

This sensor detects the bio-potential generated by the heartbeat and is configured to enable analog output by wirelessly communicating with the receiver.The analysis process is as follows.

< Sensor specification >

- Reception range: 80~100 cm
- Transmit/receive frequency: 5 kHz ± 10%
- Receiving current consumption: 30~55 µA
- Transmitting/receiving operating temperature: 0~60 ℃

< Pin Connection>

- Connect AI0+ terminal of myDAQ to SIG1 terminal of Analog Proto board connector
- Connect the AI0- terminal of myDAQ to the GND terminal of the Analog Proto board connector
- Connect the +5V DC output of myDAQ to the 5V terminal of the Analog Proto board connector
- Connect the DGND terminal of myDAQ to the GND terminal of the Analog Proto board connector

Open vernier_heart_rate.vi> at the end of the palette.

Open the block diagram, right-click DAQ Assistant, click <Properties> in the submenu, and select <Differential> in <Terminal Settings> in Voltage Input Settings.

Fig 2 shows the posture condition for heart rate variability measurement.

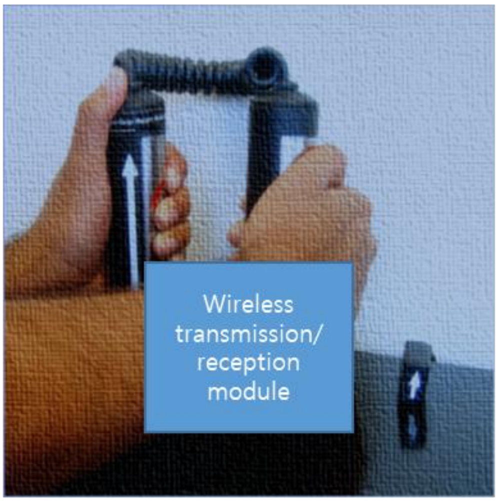


Figure 2. Proper positioning of hand-grip pacemakers

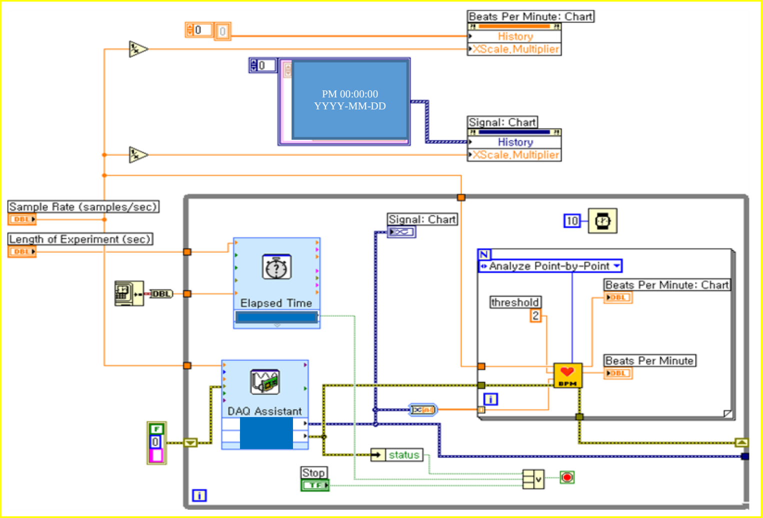


Figure 3. Execution screen and block diagram of the heartrate VI

Fig 3 is a block diagram explaining the execution process of heart rate VI.With the direction of the arrow on the pre-transmission/reception module facing upward, VI was executed while holding the grip of the hand-grip heart rate monitor.

2.3 Skin Surface Temperature Measurement

Surface temperature sensors are designed for use in situations where flexibility is required, such as low thermal mass or skin temperature measurement.The thermistor is exposed, so it has a very fast response speed and can be used in air and water.

<Skin temperature sensor specification >

- R Temperature range: -25 to 125℃

- The maximum temperature that the sensor can withstand without damage: 150℃
- Temperature sensor: 20 kΩ NTC Thermistor
- Accuracy: ±0.2℃ at 0℃, ±0.5℃ at 100℃
- Response time (90% change time): 50 s (still air), 20 s (moving air)

< Pin Connection >

- Con Connect AI0+ terminal of myDAQ to SIG1 terminal of Analog Proto board connector
- Connect the AI0- terminal of myDAQ to the GND terminal of the Analog Proto board connector
- Connect the +5V DC output of myDAQ to the 5V terminal of the Analog Proto board connector
- Connect the +5V DC output of myDAQ to the 5V terminal of the Analog Proto board connector
- Connect the DGND terminal of myDAQ to the GND terminal of the Analog Proto board connector

Open the block diagram, right-click DAQ Assistant, click <Properties> in the submenu, and select <Differential> in <Terminal Settings> in Voltage Input Settings.Then, touch the thermometer to the skin and run VI.

2.4Muscle Fatigue Measurement

A handheld dynamometer, a strain-gage based on static contraction, was used to measure grip pressure and pinch pressure.

In order to determine the degree of muscle fatigue, a handheld dynamometer was used in conjunction with an EMG sensor.

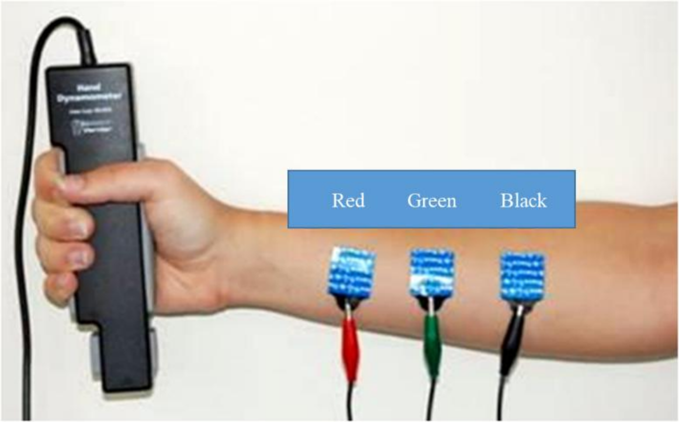


Figure 4. Measurement of muscle fatigue using a grip dynamometer sensor (3-electrode attachment method)

Fig 4 shows the process of measuring muscle fatigue using a grip dynamometer sensor by attaching three electrodes.

<Grip dynamometer sensor specification >

- Operating range: 0 ~ 600 N
- Safety range (maximum force that the sensor can withstand without damage): 0 to 850 N
- Resolution : 0.2141 N
- Accuracy :±0.6 N
- Power : 7mA @ 5VDC Response time (90% change time): 50 s (still air), 20 s (moving air)

< Pin Connection >

- Connect AI0+ terminal of myDAQ to SIG1 terminal of Analog Proto board connector
- Connect the AI0- terminal of myDAQ to the GND terminal of the Analog Proto board connector
- Connect the +5V DC output of myDAQ to the 5V terminal of the Analog Proto board connector
- Connect the DGND terminal of myDAQ to the GND terminal of the Analog Proto board connector

III. RESULTS AND DISCUSSION

3.1 Analysis of the Heart Rate Variability (HRV)

The heart rate variability analysis task was greatly simplified through an open-source statistical environment package, and its usefulness could be confirmed through actual examples.

A graphic representation and Biomedical Toolkit were utilized to measure heart rate variability using a graphic-based software platform, NI Inc. program.

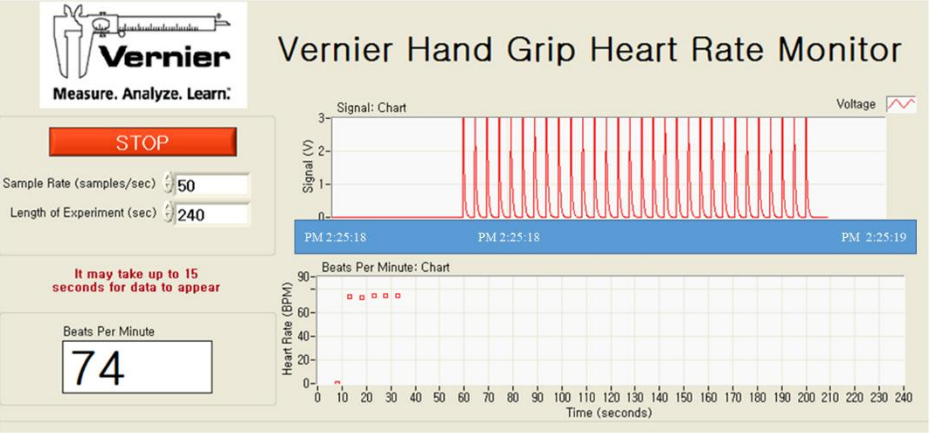
VLF Power 190 ms2
LF Power 120 ms2
HF Power 760 ms2
VLF 17 %
LF 11 %
HF 72 %
LF 8,63 n.u.
HF 56,9 n.u.
LF/HF 0,15

Signal Analysis: AR Spectrum

Operation

Figure 5. Heart rate variability data extraction

The results measured using the heart rate variability data extraction program are shown in Fig 5 and Fig 6.



Vernier Hand Grip Heart Rate Monitor

Sample Rate (samples/sec) 50
Length of Experiment (sec) 240

It may take up to 15 seconds for data to appear

Beats Per Minute 74

Figure 6. Heart rate data extraction using hand grip dynamometer

Since ECG signals are recorded with a variety of noises, including muscle noise, grid noise, and circulatory noise, these noises must be suppressed in order to obtain the necessary correct information from the signal [6-7].

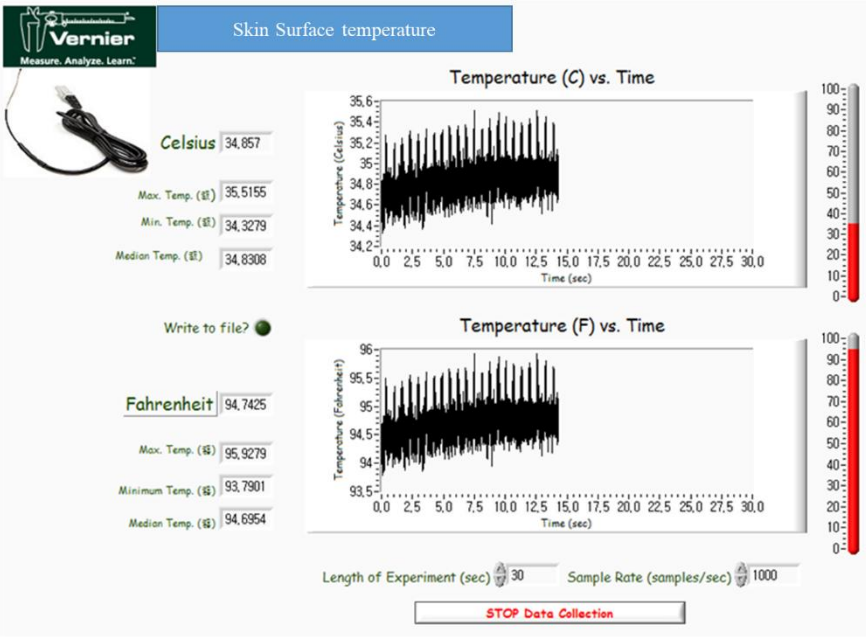
Therefore, the high and low frequency components have been removed from the signal shown in Fig 5.

3.2 Analysis of the Skin Surface Temperature

Temperature data measured wirelessly was transmitted to a prediction program connected to the receiver and displayed. These data are closely related to wireless communication performance and could only be extracted by connecting a domain oscilloscope to the MCU's MISO port.

Fig 7 shows the device and measurement data for extracting skin surface temperature.

There is also a study by another researcher comparing skin temperature with a predictive program using an infrared thermometer at the same time.



Celsius 34.857

Max. Temp. ([illegible]) 35.5155

Min. Temp. ([illegible]) 34.3279

Median Temp. ([illegible]) 34.8308

Write to file? ●

Fahrenheit 94.7425

Max. Temp. ([illegible]) 95.9279

Minimum Temp. ([illegible]) 93.7901

Median Temp. ([illegible]) 94.6954

Length of Experiment (sec) 30

Sample Rate (samples/sec) 1000

Figure 7. Skin surface temperature data extraction

Skin temperature measurement is becoming more and more important in the field of measurement using virtual instrument measurement technology.

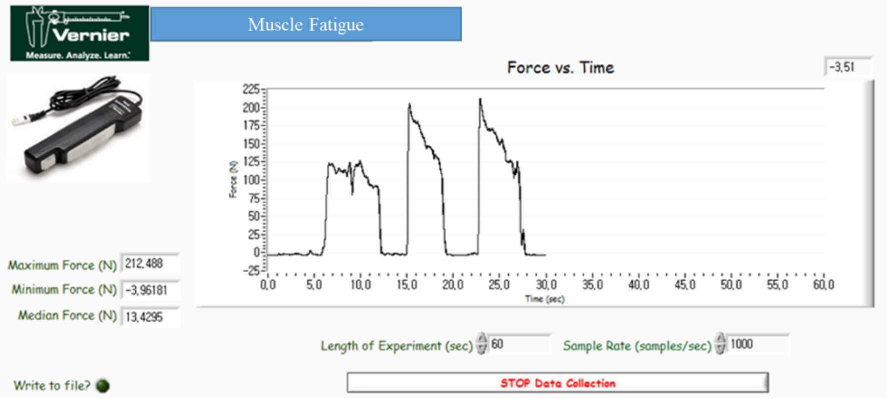
It is expected that virtual machines can also solve nonlinear compensation by making full use of computer, storage, display and other intelligent functions through fitting or interpolation correction [8-9].

3.3 Analysis of the Muscle FatigueUsing Dyanamometer

The relationship between the handgrip and surface EMG signal characteristics of the forearm muscle was investigated through a prediction program.

Surface EMG signals and grip force were simultaneously detected and recorded by the EMG-Force amplifier and prediction program.

Fig 8 shows the result of extracting muscle fatigue data using a dynamometer.



Maximum Force (N) 212,488
Minimum Force (N) -3,96181
Median Force (N) 13,4295
Length of Experiment (sec) 60
Sample Rate (samples/sec) 1000

Figure 8. Muscle fatigue data extraction using dynamometer

There was a positive correlation between the surface EMG and the level of grip strength, and the stronger the grip strength when using both hands, the more the surface EMG characteristics increased.

Portable dynamometers, which are strain gauges based on static contraction (isometric), are used to measure grip pressure and pinch pressure and can determine muscle fatigue. It can be used alone with a portable dynamometer or in conjunction with an EMG sensor for detailed measurement of muscle activity [10].

Electromyography is used as a method to evaluate the overall behavior of muscle fibers constituting muscles through a non-invasive technique, and these signals are generated by ion exchange through the membrane of muscle fibers due to muscle contraction.

Electromyography was widely applicable in determining muscle fatigue.It has been reported that surface EMG enables various applications in various types of sports, and that there is a linear relationship between muscle fiber frequency and propagation speed.

Muscle fatigue is defined as a variable decrease in muscle to generate force, and the fatigue index can be known through spectroscopic analysis of the signal [11].

Based on the average frequency and maximum Root Mean Square amplitude of the EMG signal, it is expected that it can be used to detect fatigue during an athlete's exercise routine.

3.4Analysis of the Noninvasive Blood Pressure

Utilize the analog input channels of NI hardware (NI ELVIS II or NI DAQ hardware) to control NIBP devices and acquire pressure signals.Provides NIBP analysis function using oscillometric method for research purposes.

Fig 9 shows data obtained by extracting blood pressure using a non-invasive method.

Pressure signals were obtained from an oscillometric method with sampling frequency and a system that non-invasively measures blood pressure changes.

In order to transmit the received signal in the form of digital data, the analog frequency set in the microcontroller software was digitized with high accuracy.

Blood pressure signals were recorded with very low noise, and systolic and diastolic blood pressures could be calculated in the predictive software.

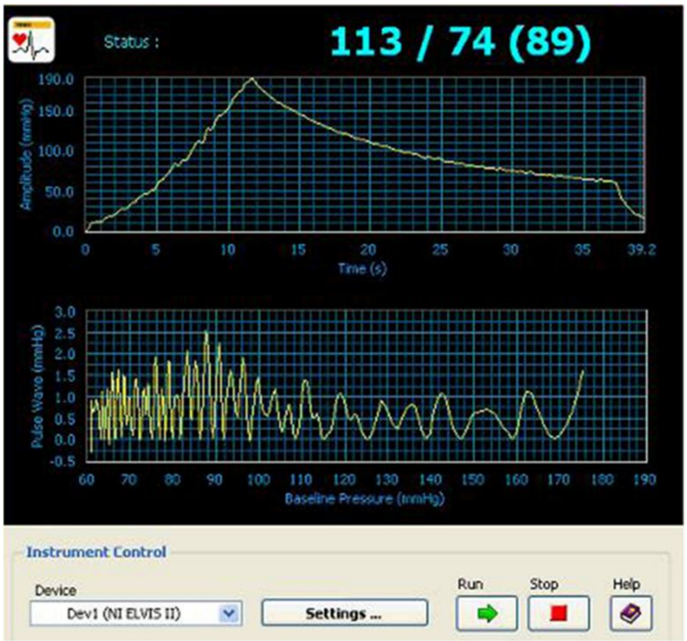


Figure 9. Blood pressure data extraction

3.5ECG Feature Extraction

ECG signals with standard waveforms, including P waves, QRS complexes and T waves, were obtained by placing electrical sensors on the body or handle.

(a) ECG extractor ON status

(b) ECG extractor OFF status

Figure 10. Electrocardogram feature extraction data

Fig 10 shows the state of extracting characteristic data of electrocardogram.As a result of a graphical recording of the electrical activity of the heart using a non-invasive method of examination, the ECG appears as alternating atrial and ventricular contractions.

The electrical movement of the heart rate is measured to reflect the heart condition, and the X-axis and Y-axis of the electrocardiogram waveform expressed in seconds as an isoelectric line are expressed in millivolts.

Bradycardia, a condition such as hypothyroidism, may be related to a medical problem.Bradycardia is defined as a heart rate of less than 60 beats per minute, but symptoms rarely appear until it drops below 50 bpm when a person is completely at rest [12-13].

Bradycardia numbers can vary because children and small adults tend to have a faster heart rate than normal adults.

Time domain analysis extracts many measurements from the raw RR interval signal.The simplest variable derived directly from the RR interval signal is the time domain parameter, and the RR signal is obtained by the QRS complex detected on the ECG.

IV. CONCLUSION

In this paper, data simulation results related to bio-signals were reviewed using open-source statistical environment software for heart rate variability analysis.

Using the kit's application, it was possible to analyze heart rate variability (HRV) and measure blood pressure by extracting functions from electrocardiogram (ECG) signals. In addition, NI hardware and applications in the kit were used to generate standard analog, biomedical signals to verify biomedical instrument validation and testability.

Using the prediction program as an implementation tool, we detected various bio-signals and analyzed the relationship between the sensing systems.

The analysis result derived here is expected to provide a good solution to be used when there is an abnormality in the actual situation.

Through this experiment, it was possible to predict the characteristics without the actual analysis equipment when the simulation analysis tool and the experimental equipment were combined for the bio-signal characteristics.

In future research, we plan to proceed in conjunction with the results of this study for the development of artificial intelligence-based bioanalysis equipment.

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