Bio-Sensing and Bio-Feedback Instruments
--- DoubleMyo, MuseOSC and MRTI2015 ---

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ABSTRACT

This report is about new instruments applied by biological information sensing and biofeedback. There were three projects developed in 2015 - (1) a new EMG sensor "Myo" customized to be used as double sensors, (2) a new brain sensor "Muse" customized to be used by OSC, and (3) an originally developed "MRTI (Multi Rubbing Tactile Instrument)" with ten tactile sensors. The key concept is BioFeedback which has been receiving attention about the relation with emotion and interoception in neuroscience recently. The commercialized sensors "Myo" and "Muse" are useful for regular consumers. However, we cannot use them as new interfaces for musical expression because they have a number of problems and limitations. I have analyzed them, and developed them for interactive music. The "DoubleMyo" is developed with an original tool in order to use two "Myo" at the same time, in order to inhibit the "sleep mode" for live performance on stage, and in order to communicate via OSC. The "MuseOSC" is developed with an original tool in order to communicate via OSC, in order to receive four channels of the brain-wave, and 3-D vectors of the head. I have reported about the "MRTI2015" in past conferences, so I will introduce it briefly.

1. INTRODUCTION

As a composer of computer music, I have long been developing new musical instruments as a part of my composition[1]. The appearance of new sensor technology, interfaces, protocols and devices have led to new concepts in musical instruments and musical styles. I particular, biological sensors for EMG/EEG/ECG signals are very useful for musical application because the bio-information is tightly concerned with the human performer in a musical scene.

Inspired by "BioMuse" from Atau Tanaka[2] and research by R. Benjamin Knapp[3], I have developed five generations of EMG sensors from the 1990's, and developed many EMG instruments (called "MiniBioMuse" series) and methods of pattern recognition of performances[1]. The biggest advantage of EMG sensing is its short latency / fast response compared with other interfaces like switch, shock, pressure and CV sensors. At the 5th generation EMG sensor, I developed a XBee wireless interface, so the musical performance could be separated from the system. The freedom of not having cables is an important factor in live performances.

On the other hand, the private development of systems had a disadvantage in that the system is not as compact as mass-production. Therefore, I have recommended arranging or remodeling consumer products in developing new instruments. This is very good for education and hobby - arranging / remodeling everything (sketching) for original and customized use, and of course, in computer music and media arts.

Recently we can get many smart systems in the bio-sensing field - thanks to sketching (physical computing), 3-D printing and Open-source culture. Past bio-sensors were developed for medical use, so the systems were quite expensive. However, we can get smart, lightweight and usable bio-sensor systems now; the systems are not regulated for medical use, only for consumer / hobby use. In this paper, I will report two test cases of bio-sensors arranged / remodeled for computer music use.

2. MYO AND MYO-OSC

The Myo[4] (Figure 1) was supplied by Thalmic Co. in 2015. The "Myo armband" is constructed with eight blocks connected by a rubber connector, has eight channels EMG sensors and 3-D direction sensors, 3-D gyro sensors and 3-D acceleration sensors. The communication of Myo vs host PC is by Bluetooth, using the specialized interface "USB-Bluetooth dongle".

Figure 1. The "Myo" armband.

A specialized application "Myo armband manager" is supplied, and normal users can register the standard five poses to the application - fisting the palm, opening the palm, turning the palm to the left, turning the palm to the right and relaxing the palm. The specialized mapper in the "Myo armband manager" can assign these five poses into any keyboard codes, so normal users can control any commands with any other applications. For example, one pose changes the page of the presentation and another pose starts / stops the movie.

The standard Javascript tool "myo.js" for "Myo armband manager" can display all sensors information on the HTML screen in realtime (Figure 2). However, this Javascript interface "myo.js" using WebSockets cannot communicate with Max6.

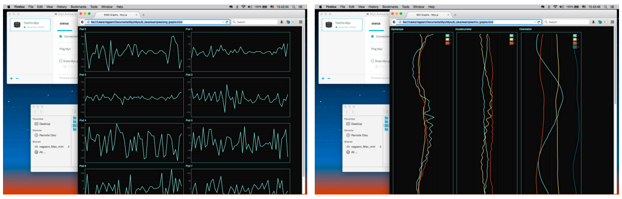

Figure 2. Sensors data from "Myo" armband.

Next, I found the tool "myo-processing" (Figure 3 shows a screenshot). The standard sketch of Processing "myo-processing" can communicate with the "Myo armband manager", and displays all the sensor information.

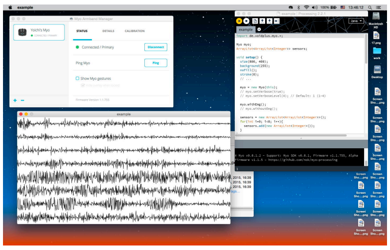

Figure 3. Screenshot of the "myo-processing".

I have already experienced multi-process communication within the "Processing - Max6 - SuperCollider" system. I arranged the myo-processing sketch by embedding the OSC module, and succeeded in realizing "Myo - Processing - Max6" system, not only receiving Myo's 8+3+3+3 sensors data but also sending a "ping(vibration)" command from Max6 (Figure 4).

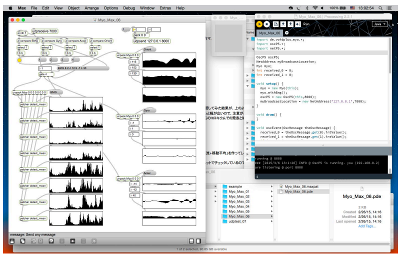

Figure 4. Screenshot of Myo-Processing-Max6.

After mastering the communication with Myo, I recalled that I have performed on many stages with my originally-developed EMG sensors (Figure 5). The important conditions for the live performance of computer music are - stability, long battery life, reproducibility of rehearsal, and system reliability. The "Myo" has powerful CPU/firmware, however the intelligent "sleep" function works against realtime performance. As is well known, the silent / still scene is an important part in music, but the "Myo" sleeps when the performer relaxes or is still on the stage.

The other request to the "Myo" is - to use both arms at the same time, like my past EMG sensors. When I added the second "Myo", the "Myo armband manager" could detect each Myo on the connecting window. However, there was no method to identify double "Myo"s with the Processing tools and the Java tools.

Figure 5. Performances with original EMG sensors.

3. THE DOUBLE MYO

In researching the Myo developers site, I found that the application "MyOSC" can deal with two "Myo"s individually. This application receives individual 3+3+3 sensors data from the double Myo, however, it can deal only with 3+3+3 data, and it cannot deal with the EMG data.

Hereon, I have decided to develop my original tool with the Xcode IDE, as the frontal attack. I analyzed the developers references deeply and tested many experimental prototypes. Eventually, I succeeded in communicating with "Myo" directly without the Processing-based tool. Figure 6 shows a screenshot - the Max6 can communicate with Myo via OSC by my original interface application.

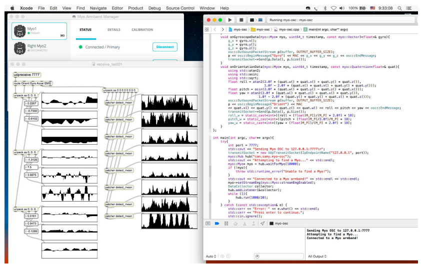

Figure 6. Screenshot of Myo-OSC-Max6.

Finally, I have completed developing an application that can communicate with double "Myo" individually and set the "non sleep" command (Figure 7). This meant that I can use "Myo"s in a computer music performance - with both my arms.

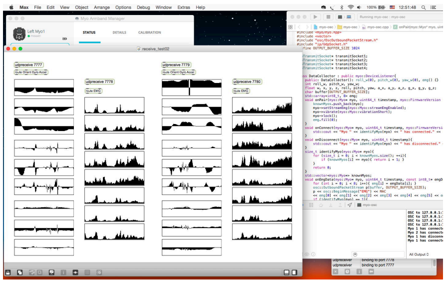

Figure 7. Screenshot of the "double Myo" test.

After that, I developed an experimental system to demonstrate the "doubleMyo" (Figure 8). With both eight channels EMG signals, this system generates 16 channels FM oscillator sound and realtime 3-D CG images (flying particles) with Open-GL. I have a plan to compose a new piece using this system.

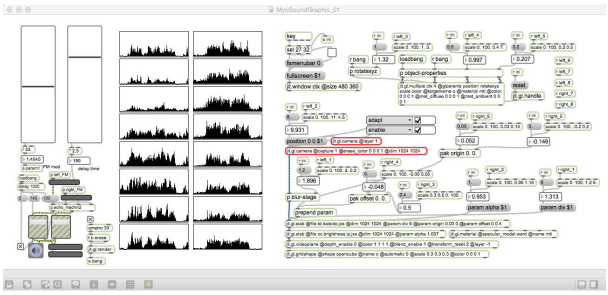

Figure 8. Screenshot of the DoubleMyo application.

4. THE MUSE

The brain sensing headband MUSE[5] (Figure 9) has been developed for relaxation and mental exercise. It was supplied by InteraXon Co. in 2015. MUSE has five-electrodes on the forehead, the second electrodes to ear-lobe, and a three-dimensional acceleration sensor. It is a compact lightweight inexpensive apparatus for transmitting biological information to the host via Bluetooth.

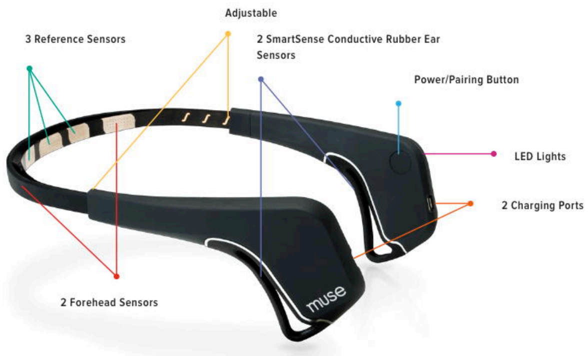

Figure 9. The "MUSE".

The regular user of MUSE uses a specially supported application for iPhone/iPad. The normal purpose of MUSE is mental exercise and mental health for amateurs - (MUSE is not authorized for medical usage). Figure 10 shows the usage style of MUSE and the result screen of the MUSE application. At first, people register their profile online. Every time after the brain exercises (relax), the users personal data is stored into the system, and people will try to realize "better relax on data" again with each training.

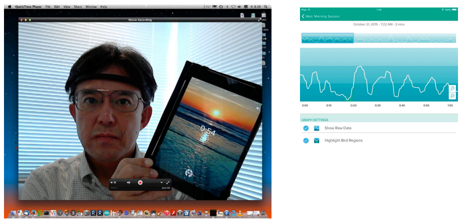

Figure 10. The "MUSE" usage and the application.

The "Myo" needs a special interface "USB dongle" to communicate via Bluetooth. On the other hand, the "MUSE" uses regular Bluetooth of the host system. I was not interested in the mental exercise, so I started to receive MUSE's Bluetooth information by Max's serial object (Figure 11).

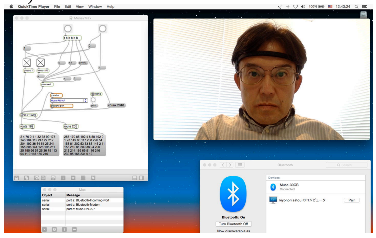

Figure 11. Directly receiving the MUSE Bluetooth(1).

I tried to understand the complicated definitions and protocols of MUSE[6,7], and finally succeeded in receiving four channels of compressed brain-wave (alpha, beta, gamma and theta) data from MUSE (Figure 12).

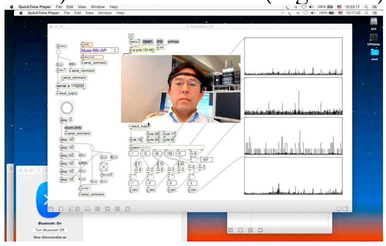

Figure 12 Directly receiving the MUSE Bluetooth(2).

5. MUSE-OSC

The disadvantage of directly receiving the MUSE via Bluetooth is dealing with high speed serial in the "Max". It is difficult to communicate with bidirectional protocol. By the way, the MUSE tool "MuseIO" supports the special protocol "like" OSC. The OSC is very familiar with "Max", so I researched the documents.

The standard "MuseIO" uses the TCP protocol which is not compatible with the OSC. I analyzed the documents and developed the special tool (Unix scripts) to set up the "MUSE" - as a UDP-based real "OSC" and notch filter option for power-line noise reduction (50Hz/60Hz). Figure 13 shows an experiment to change the filter parameter and to check the effect of noise reduction.

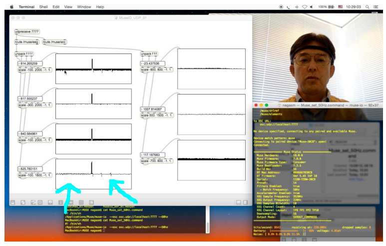

Figure 13 OSC test with the MUSE.

After the success of the OSC communication with the "MUSE", I found a big problem in using this system for musical performances. In the "mental exercise" mode, the MUSE application says "close your eyes, relax". After some minutes relaxing, the system starts. If I open my eyes and look at something, the system scolds me because so the EMG signals (around my eyes) interferes with the very weak brain signals. This means "MUSE cannot be used in a musical performance with ones eyes open". A contemplative performance (with eyes closed) can be beautiful of course. However, normally we cannot interact on the stage with other musicians in a musical session with our eyes closed.

Figure 14 shows the experiment of an AGC test. In the Max window, the vertical three graphs on the left side means the 3-D direction sensors, and the remaining nine graphs are the focus of the commentary. The left vertical four graphs are original input of the compressed brain-wave (alpha, beta, gamma and theta) from the "MUSE". With eyes closed, the brain-wave level is very small. Some of the big signals are the signals of the extraocular muscles of eye-blinks, and the signal of the facial muscles.

The center vertical four graphs are amplification to 10 times of the compressed brain-wave from the "MUSE". The brain-wave is well amplified to analyze the pattern, however the noise is overflowing the scale.

The right vertical four graphs are the AGC (automatic gain control) result. The amplification to 10 times of the compressed brain-wave from the "MUSE" is well amplified, and the noise signals are well compressed so as not to overflow. This algorithm is very simple (showed in the left side sub-patch).

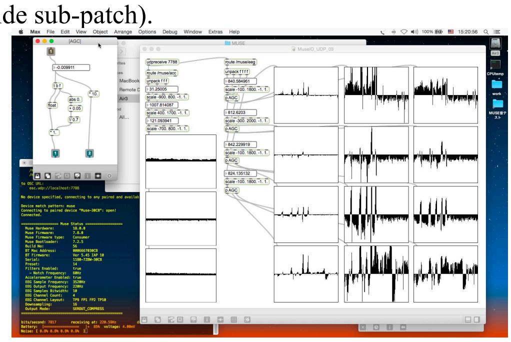

Figure 14 AGC test with the MUSE.

After this experiment, I decided that the "MUSE" should be used only as a sensor for extraocular muscles and facial muscles in musical performances. Because the time constant of the brain-wave is very big (slow reaction), this decision is effective for interactive live performances. I intend to compose a new piece using this system.

6. ADD THE MRTI2015

Working with the project "doubleMyo" and the project "MuseOSC", I developed a new instrument in 2015 featuring rubbing / tactile sensors. Because I have submitted a paper to another conference (NIME) about this, I will introduce it simply here.

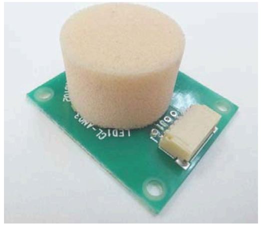

Figure 15 The PAW sensor.

The "RT corporation" in Japan released the "PAW sensor" in 2014. The "PAW sensor" (Figure 15) is a small PCB (size 21.5mm * 25.0mm, weight 1.5g) with a large cylinder of urethane foam on it. The output information of this sensor is four channel voltages which is time-shared conversion, which means the nuances of rubbing/ touching the urethane foam with ones fingers.

My first impression was that I did want to use 10 "PAW sensors" with ten fingers. If all sensors are placed on the same plane like keyboard, the style of musical performance seems unnatural, because all finger tips must not move as on a piano or organ. A cube or mechanical shape is also unnatural for fingers/hands to grasp. Finally I found an egg-shaped plastic container (Figure 16). The experimental demonstrations are on YouTube[8-10].

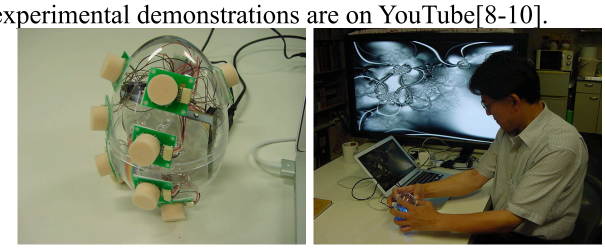

Figure 16 The new instrument "MRTI2015"(left) and its performance demo 8right).

After the three types of new instruments were developed, I aimed to mix up all sensor information, all sound synthesis parameters and all realtime graphic generation. Figure 17 shows the concept of the system, the environment is "Max7" and the communication is Bluetooth and USBserial.

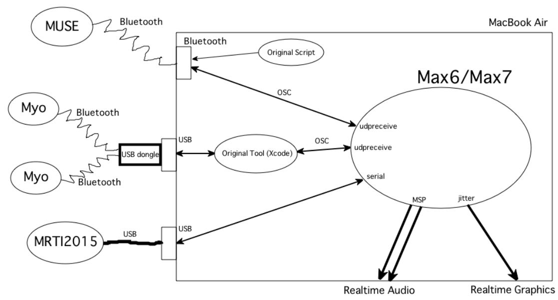

Figure 17 Mixture the three systems.

In the "Max" environments, I merged the three patches of "doubleMyo", "MuseOSC" and "MRTI2015" and tested, arranged and improved them. Figure 18 shows the testing process. I managed the OSC ports for "doubleMyo" and "MuseOSC", and merged the information using the same format/protocol for "MRTI2015" high-speed (115200) serial communication.

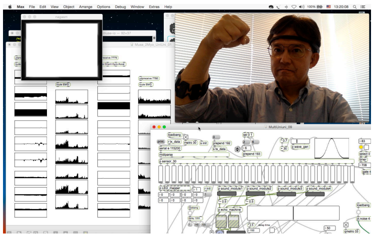

Figure 18 Mixture the three systems.

For the future tour, the "battery" issue is very important - battery life from full charge, irregular reset, auto-sleeping trouble and the calibrations. Figure 19 shows the battery check in the development experiments. The results are that the "Myo" works over 90 minutes continuously and the "MUSE" works over 3 hours after full charge, which is enough.

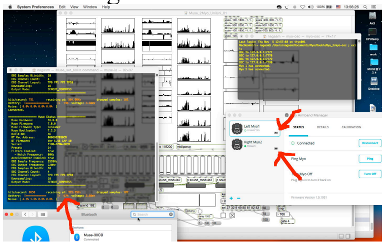

Figure 19 Battery check in the experiment.

7. DISCUSSION: THE BIOFEEDBACK AND MUSICAL PERFORMANCE

In this section, I will discuss the background of my research from the perspective of experimental psychology and brain science[3]. I have been researching bio-instruments and interactive multimedia art[11-17]. This is why I am interested in this field.

Damasio proposed the "Somatic Marker Hypothesis" in the area of brain science with the "as if loop" for the fast response in the brain (Figure 20)[18-22]. The "Somatic Marker Hypothesis" is pointed out to be the background of affective decision-making[23], or the background of interoception and emotions[24]. The interoception is a contrasting concept to the external senses (five senses). Each external sense has a specialized sensory organ. However, the interoception is organized from internal organs and the nervous system.

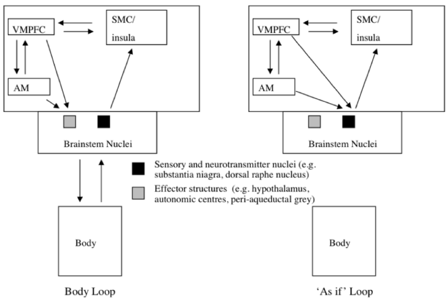

Figure 20 Somatic Marker Hypothesis [20].

As Figure 21 shows, Seth et al. proposed the interoception and biofeedback model as the background of the decision-making and feeling/emotion[25,26]. For example, the origin of exciting or dynamic emotions is from endocrine substances and hormones which are the result of human activity. The reaction time from this chemical object is long, but the "as if loop" works quickly as a short-cut in the brain. The differences between the result of the "as if loop" and the real result from the chemical response route are compared in realtime, and the prediction model is adjusted in real-time. With this biofeedback mechanism, the "adjusted difference" occurs in emotion and the decision-making.

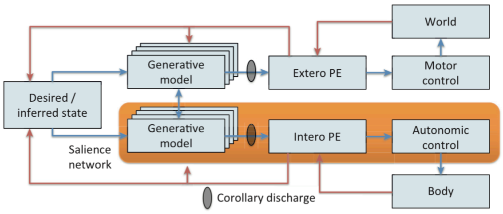

Figure 21 Seth's interoception and biofeedback model.

As Nacke et al. pointed out, bio-feedback is very important in the interaction design field[27]. There are many reports and papers on this topic, and I also reported on a EMG biofeedback game with gesture recognition system [28,29]. The subjects in the experiment do not know how to control/trim the muscle to replay the gesture with EMG sensors - this is of the interoception. However, most of the subjects can subtly control and realize the past-recorded gesture by unconscious trial and error. When the replay is succeeded by the bio-feedback graphical report, all the subjects feel happy/relaxed and positive emotions. This phenomenon will suggest great ideas to game-design, and to interactive live performance in computer music.

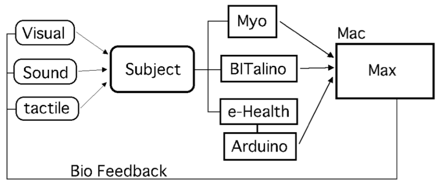

Figure 22 System design for future experiments.

Figure 22 shows the system block diagram of my future research in this field. We cannot detect the exact value of interoception because the value is chemical information or virtual in brain (in "as if loop"). So, the bio-feedback route to the subjects is well-known external senses channel - Visual, Sound and Tactile. However, the sensors to the subjects is bio-sensors - EMG, ECG, and EEG - Myo, MUSE, BITalino, e-Health and MRTI2015, etc. All sensing information is merged to the Max system and interpreted, and the visual / sound / tactile output is displayed into the subject to generate an affective response. This seems both kind of a game and kind of a mental relaxing exercise, and is a friendly interface in musical performance.

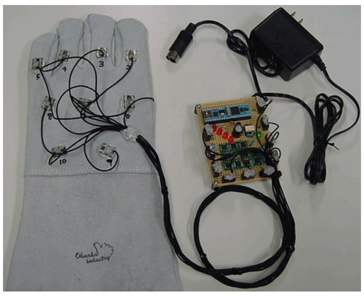

Figure 23 New tactile interface with linear actuators.

Figure 23 shows the newest experimental system of the tactile interface. I use ten pieces of "Linear Vibration Actuators" in system, controlling each vibration frequency with 32-bits resolution and high-speed response via MIDI[30], which I will report in the near future.

8. CONCLUSIONS

This report is about new instruments applied by biological information sensing and biofeedback. The perspective of experimental psychology and brain science are very interesting in considering new musical instruments and in creating new styles of music. Musical emotion is a very old theme, however, we can approach this theme now with the newest technology and ideas. I believe that computer music can open a new door in human emotion via new research.

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