MuMYO — Evaluating and Exploring the MYO Armband for Musical Interaction

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ABSTRACT

The MYO armband from Thalmic Labs is a complete and wireless motion and muscle sensing platform. This paper evaluates the armband's sensors and its potential for NIME applications. This is followed by a presentation of the prototype instrument MuMYO. We conclude that, despite some shortcomings, the armband has potential of becoming a new "standard" controller in the NIME community.

Author Keywords

MYO, wireless, accelerometer, EMG, interaction

ACM Classification

H.5.2 [Information Interfaces and Presentation] User Interfaces–Evaluation/methodology, H.5.5 [Information Interfaces and Presentation] Sound and Music Computing–Systems.

1. INTRODUCTION

In the world of NIME, we often see one of two design approaches: (a) you start with a conceptual idea and build a device to fit that idea, or (b) you start with an available controller and see what it can be used for in a NIME context. This paper follows the latter approach, exploring the new MYO controller[1] from Thalmic Labs in a musical setting.

The MYO consists of eight electromyographic (EMG) sensors that measure muscle tension, and an inertial measurement unit (IMU) with a 3D gyroscope, 3D accelerometer and a magnetometer. Data communication is wireless (Bluetooth, with its own dongle), and the device is easy to set up. The MYO is affordable, attractive-looking and appears to be solidly built. Thus, even though both IMU and EMG sensing has been used in the NIME community for decades [10, 5, 3], the MYO is the first example of an integrated and easy-to-use solution. As such, it has the potential of becoming a "standard" commercial interaction technology in the NIME community, following on from Wacom tablets, Wii controllers and Kinect sensors.

Even though the device has just started shipping, there are already a few online demo videos of the MYO being used for musical applications. Most of these applications are aimed at controlling effects or musical transitions in software like Ableton Live, such as done by Liam Lacey.[2] Thalmic Labs themselves promote the use of MYO in the large-scale, interactive DJ sets of Armin van Buuren.[3]

Figure 1: The MYO with three reflective markers, and two BioFlex EMG sensors next to the MYO.

Our goal in this paper has been to assess the MYO's potential for developing new musical instruments. The paper starts with a test of the MYO's sensing capabilities, followed by a discussion of its conceptual possibilities. Finally, our MuMYO prototype instrument is presented and evaluated.

2. EVALUATING THE SENSOR DATA

An important criterion for selecting a hardware solution for musical applications is the quality and reliability of the data it provides. In our experience, the values from manufacturers' data-sheets are less useful than testing the devices in our own lab and performance environments. We have therefore carried out an evaluation of the MYO, based on our own [8, 9, 4] and other's [11] methods for testing the quality of the data from various types of motion capture system.

2.1 Test method

All testing of the MYO was done in the fourMs motion capture lab at the University of Oslo, with a state-of-the-art, marker-based, optical motion capture system from Qualisys (with nine Oqus 300 cameras) used as a reference.

Three reflective markers were placed on the MYO, as shown in Figure 1. This allowed for calculating the 3D rotation of the armband in addition to the 3D position reported from the system. Obtaining a good reference for EMG data is difficult, since two sensors cannot be put on the same body location. However, to get an indication of the quality of the MYO's EMG data, we compared it with two BioFlex EMG sensors from Infusion Systems (used in Knapp's *BioMuse* [5]). One sensor was placed on the anterior side and one on the posterior side of the forearm.

Motion capture data was recorded at 120 Hz in the Qualisys Track Manager. The data was also streamed through

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[1] `https://www.thalmic.com/en/myo/`

[2] `https://www.youtube.com/watch?v=MnIv9Wi26bc`

[3] `https://www.youtube.com/watch?v=Wrc1c8g2FPk`

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OSC to a separate computer, and recorded together with data from the MYO armband and the BioFlex sensors with a custom built Max patch. The MYO data was obtained using Samy Kamkar's *myo-osc*[4] with a slight modification to include streaming of the raw EMG data. The sampling rates for MYO data are fixed at 200 Hz for EMG and 50 Hz for the inertial sensors. The analysis has been done in Matlab using the MoCap Toolbox [1] and custom built scripts.

To test the MYO in a range of conditions, we recorded three different scenarios ranging from a controlled condition far from a real use scenario, to a condition closer to natural motion but with less control over the motion pattern: (1) MYO lying still on the floor, (2) positioned on the arm of a person sitting still with the arm on a note stand, (3) MYO positioned on the arm of a person moving about in space with (a) repeated circular motion, (b) repeated impulsive motion, and (c) free motion in the air. Each test was done twice. The results are presented in the sections below.

2.2 Noise level

A stationary recording of the MYO on the floor was done to evaluate the basic noise-level in the acceleration data, including any filtering that might be applied within the MYO itself. Unfortunately, the MYO has a built-in idle filter, which disables data streaming after 30 seconds of inactivity. To only include data from the time period when the MYO was stationary on the floor, a 20 second period was extracted from each of the two recordings for the analysis.

The noise level (Table 1) was estimated as the standard deviation of the absolute acceleration (magnitude of the acceleration vector). When lying on the floor, the recorded noise level of the MYO was 19.0 mm/s^2. In comparison, the noise level was 31.4 mm/s^2 for the recording of a subject wearing the MYO while sitting still. The latter result could indicate that the noise-level of the sensors themselves is far lower than the threshold of human motion, even when trying to sit still. However, the analysis of the Qualisys motion capture data revealed that the estimated acceleration was fairly similar for the two conditions (on the floor or worn on the arm), even when using different filter length (Savitzky-Golay) during derivation in the MoCap Toolbox. It should be noted here that the derivation of the Qualisys position data results in an accentuation of the noise level.

Table 1: Noise values for stationary experiment (SD of absolute acceleration in mm/s^2). FL indicates different filter lengths in the acceleration estimation.

	On floor	Worn on arm
MYO	19.0	31.4
Qualisys, FL = 7	12.9	14.0
Qualisys, FL = 3	36.2	31.8

Even with some uncertainty about the absolute noise level of the acceleration data, the levels compare to the state-of-the-art MoCap system from Qualisys and to the levels we have previously found in iPod acceleration data (noise levels between 16 and 23 mm/s^2 [8]).

2.3 Rotational drift

IMU's are suspect to drift when used for estimating position or orientation [9]. To evaluate rotational drift in the MYO, we observed the evolution of the *yaw*, *pitch* and *roll* angles individually for the stationary recording. Figure 2 shows an initial drift in the *yaw* angle of about 3.7 deg/s, and then slowly converging to a steady orientation. A similar drift was found in the *roll* angle. For the *pitch* angle the drift was less than 0.1 deg/s. Since the MYO's magnetometer should be sufficient to prevent *yaw* drift, we suspect that high-order on-device filtering is the cause of the drift.

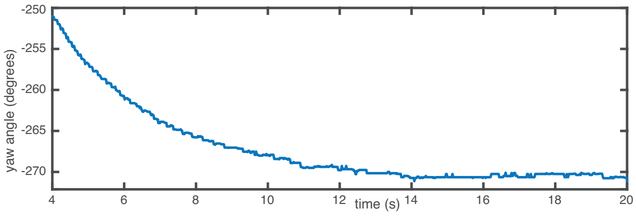

Figure 2: Yaw drift while lying still on the floor.

The rotational drift was reduced considerably when a user wore the MYO. A total drift of 4 degrees was seen in the *roll* angle in a three-minute recording. Again, the highest drift was in the initial frames, now peaking at 0.14 deg/s.

2.4 MYO in motion

To evaluate the quality of the accelerometer data for free motion, the test user conducted a fast, free motion sequence. The data from the two devices are different, as the MYO provides accelerometer data including gravitational pull. As such a quantitative comparison between the two streams would not be appropriate. However, plots of the MYO and Qualisys data (Figure 3) reveal that the same peaks are picked up by both systems.

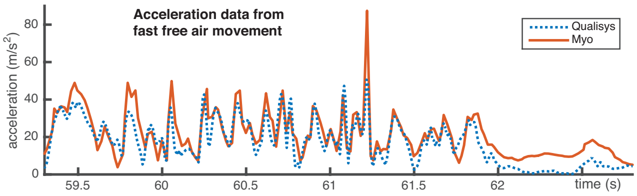

Figure 3: The acceleration magnitude data for a free motion sequence reveal a similar pattern.

2.5 EMG data

The MYO contains eight EMG sensors located around the arm of the user, and outputs the raw EMG data as well as the classification result of certain predefined actions: (1) making a fist, (2) tapping or spreading the fingers, and (3) waving to the left or right. The frame rate of the EMG data is 200 Hz, streaming 8 channels of 8-bit data.

The MYO and the two BioFlex EMG sensors were first tested individually, to allow for optimal placement of the sensor on the lower arm. To measure the noise level, we recorded data from the sensor while the user was resting the arm on a note stand. Comparing the RMS value of the recording to the maximum contraction, the noise levels (in dBFS) were -12.9 for the BioFlex and -11.9 for the MYO.

A qualitative assessment of the EMG data was done by inspecting plots of the free motion recording (excerpt in Figure 4). Here both systems were attached at the same time, as shown in Figure 1. The plots show a similar trend, but the 8 sensors in the MYO are able to capture more detailed information than the two large BioFlex sensors.

2.6 Timing

The time lag between the two data streams was estimated by upsampling the MYO data to the Qualisys' frame rate (120 Hz), and performing a cross correlation between the absolute acceleration of the two data streams as illustrated in Figure 5. On average, the MYO data stream lagged 25 ms behind the Qualisys stream.

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[4] `https://github.com/samyk/myo-osc`

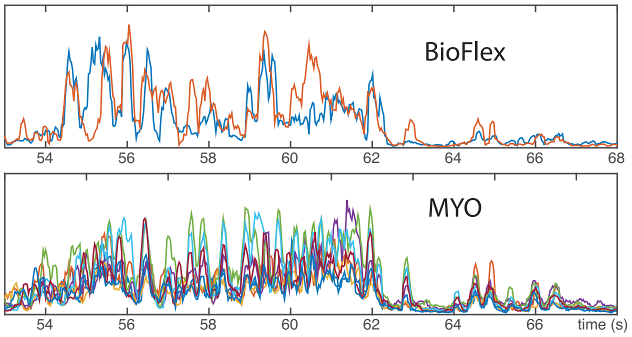

Figure 4: Data from the MYO and BioFlex sensors (RMS value) for a short excerpt of free motion. The MYO data shows more detailed information than the BioFlex data.

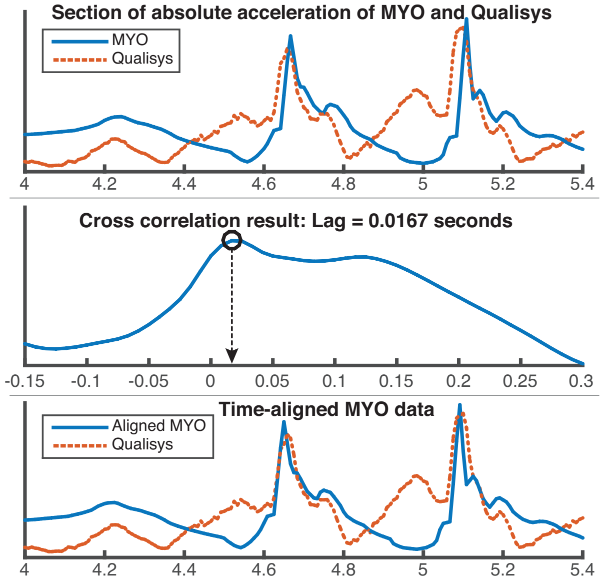

Figure 5: Cross correlation between MYO and Qualisys data streams.

Across all the recordings, the average time difference between successive frames in the MYO data stream was 20.02 s, indicating a marginally lower frame rate than the 50 Hz specified by Thalmic Labs. The standard deviation varied between 4.3 and 5.0, indicating that some jitter occurs. Still, as shown in Table 2, the MYO jitter is much lower than the EMG data stream we recorded from the BioFlex, or in our previous measurements of iPhone data [8].

Table 2: Comparison of jitter (SD of inter-frame time difference) for some systems. The numbers are averaged across all recordings.

	MYO	BioFlex	iPhone*
Mean time between frames	20.02	15.7	16.7
Mean of SD for all recordings	4.5	19.1	18.1

*result from [8]

3. MuMYO PROTOTYPE

To test the MYO for musical applications, we have developed a prototype instrument in Max7. As opposed to some of the other musical applications that have been developed for the MYO, in which the device has mainly been used for triggering and controlling ongoing musical processes, our focus has been on developing a directly playable *instrument*.

3.1 Conceptual issues

The MYO's sensing capabilities poses some interesting conceptual challenges. On the one hand, the MYO is an "open-air" controller, which opens for exploring mapping strategies developed for other types of motion capture system [9]. However, since it only senses activity in one arm, the MYO affords one-arm control actions. This makes it conceptually similar to the actions performed with, say, a Wii controller. That said, being a "touch-less" device [11], also makes it difficult to apply methods developed for hand-held motion capture devices [7].

Following the terminology from [2], we may talk about three types of control action in musical instruments: *excitation*, *modification* and *selection*. The latter type is discrete in nature, based on selecting a particular setting in the instrument before starting to play, while the two former can be either discrete or continuous [6].

In our opinion, the MYO's most compelling feature is the tracking of *both* motion and muscle activity. This may help in solving the problem of inertial sensors always being "on", that is, how to extract meaningful *actions* from the continuous stream of motion data. The muscle sensing, and classification of these into discrete control actions, allow for both selection and discrete excitation actions, while the motion sensing allows for continuous excitation and modification. Together these actions make it possible to create conceptually better action-sound relationships.

MuMYO includes five modes, which allow for testing a variety of excitation, modification and selection actions: (1) setup mode, sound selection, (2) melody control with sound-modifying actions, (3) continuous tones with sound-producing actions, (4) impulsive sounds (drum kit) with sound-producing actions, and (5) a combination of 3 and 4. The basic features of the prototype are presented online.[5]

3.2 Selection actions

The built-in EMG classifier is used for selecting parameters in the prototype. First, the *Wave In* and *Wave Out* actions navigate back and forth in a sound bank when the instrument is in "setup mode". These actions also trigger a sound, and are, as such, used for both selection and excitation. In Mode 2, the *Wave In* action starts the automatic triggering of tones. Although this action starts the sound, we argue that it is *not* a sound-producing action, but rather a *selection* between turning the stream of tones on/off. Modes 3 and 5 use the *pitch* angle to select the musical pitch of the tone before the sound-producing action is performed.

3.3 Sound-producing actions

In Mode 3, sounds are produced when the arm of the user moves with a certain velocity, and stops when the user stops moving. This is implemented with a threshold on the vector magnitude of the gyroscope data. The user could potentially move fast without rotating, and thus not exceeding the threshold. This, however, was never a problem in our user test. In Mode 4, we investigate the triggering of drum sounds based on defining high and low thresholds on each of the three axes of the gyroscope. For instance, a bass drum is triggered when the wrist is rotated inwards with a certain speed (gyroscope *roll* below a threshold value). Muscle tension is also used, a higher note velocity is set when the overall muscle activity is high. Mode 5 used the same drum actions in combination with sound-producing *Wave In* actions to trigger continuous tones.

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[5] `http://fourms.uio.no/projects/mumyo`

3.4 Sound-modifying actions

In Mode 3 (continuous sounds), multidimensional timbral control is available. The sensor *pitch* angle controls the center frequency of a band-pass filter, and the vector magnitude of the gyroscope data controls both the amplitude of the sound and the frequency and intensity of an amplitude modulation applied to the signal. In Mode 5, the *fist* pose is used as a selection action that enables a sound-modifying action: when closing the hand, the user is able to modulate the pitch of the playing tone by moving the hand up or down. Finally, in all modes, the EMG data is used to control the delay time and feedback of a delay loop. The delay time is scaled between 10 and 50 ms, and the feedback level is pushed towards 1, causing a drastic inharmonic effect when the muscle activity is high.

4. USER TESTING

To evaluate MuMYO, we conducted an informal user test at an "open day" event for 15-year-old students at a local high school (Figure 6). The instrument drew a lot of attention and the testers were enthusiastic about the interaction. Most of the test persons were only allocated a few minutes to try the device, as people lined up wanting to try it out.

The general impression from the test was that users had no problem understanding how to control the instrument in the different modes when given instructions on how to do so. The main challenge was the inaccuracy of MYO's EMG classifier. Timing and accuracy is critical for sound excitation [12], and misclassifications happened quite often, albeit irregularly, for several of our test persons. One explanation for this, is poor contact between the EMG sensors and the skin for users with thinner arms than an average adult.

Apart from the misclassification problems, users quickly understood the selection mechanisms and were able to select sounds from the sound banks and tones in different registers. The continuous sound-producing action in mode 3 (based on the magnitude of gyroscope data) proved to be intuitive, and combined well with the timbral control parameters. The users' ability to trigger impulsive tones varied considerably, however. Some were able to obtain precision in their timing and sound selection, while others struggled to use the rotational axes as sound triggers. The users that explored this mode the longest were able to learn more precise control, suggesting that rehearsal is necessary to use MuMYO in this mode. It should be noted that with the short time available, none of the testers reached a level of proficiency where they were able to keep a steady "groove".

The control domain that engaged the test persons the most was the use of muscle tension as input data to the delay loop. Most people are used to controlling their mobile phones with actions such as tilting or shaking. The use of EMG data, however, was unfamiliar to everyone, and the excitement of this "hidden" control parameter was easy to spot among the testers.

5. CONCLUSIONS

The MYO armband is a promising interface for musical expression. Our sensor evaluation shows that the quality of the motion and muscle sensing data is sufficient for sound production and modification. The weakest part as of now is the limited number of built-in classification actions, and the occasional misclassifications that occur. However, the easily accessible EMG data opens a new interaction mode to a larger user group, so we anticipate interesting musical outcomes with the MYO in many years to come.

Figure 6: User test of the MYO-music prototype.

6. REFERENCES

[1] B. Burger and P. Toiviainen. MoCap Toolbox – A Matlab toolbox for computational analysis of movement data. In R. Bresin, editor, *Proceedings of the Sound and Music Computing Conference*, pages 172–178, Stockholm, 2013.

[2] C. Cadoz and M. M. Wanderley. Gesture—Music. In M. M. Wanderley and M. Battier, editors, *Trends in Gestural Control of Music [CD-ROM]*, pages 71–94. IRCAM, Paris, 2000.

[3] B. Caramiaux, M. Donnarumma, and A. Tanaka. Understanding gesture expressivity through muscle sensing. *ACM Trans. Comput.-Hum. Interact.*, 21(6):31:1–31:26, Jan. 2015.

[4] A. R. Jensenius, K. Nymoen, S. A. Skogstad, and A. Voldsund. A study of the noise-level in two infrared marker-based motion capture systems. In *Proceedings of the Sound and Music Computing Conference*, pages 258–263, Copenhagen, 2012.

[5] R. B. Knapp, J. Jaimovich, and N. Coghlan. Measurement of motion and emotion during musical performance. In *3rd International Conference on Affective Computing and Intelligent Interaction and Workshops*, pages 1–5, 2009.

[6] T. Kvifte and A. R. Jensenius. Towards a coherent terminology and model of instrument description and design. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 220–225, Paris, 2006.

[7] K. Nymoen, S. A. Skogstad, and A. R. Jensenius. Soundsaber — a motion capture instrument. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 312–315, Oslo, 2011.

[8] K. Nymoen, A. Voldsund, S. A. Skogstad, A. R. Jensenius, and J. Torresen. Comparing motion data from an iPod touch to a high-end optical infrared marker-based motion capture system. In *Proceedings of the International Conference on New Interfaces For Musical Expression*, pages 88–91, Ann Arbor, Michigan, 2012.

[9] S. A. Skogstad, K. Nymoen, and M. Høvin. Comparing inertial and optical mocap technologies for synthesis control. In *Proceedings of the Sound and Music Computing Conference*, pages 421–426, Padova, 2011.

[10] A. Tanaka. Musical technical issues in using interactive instrument technology with application to the biomuse. In *Proceedings of the International Computer Music Conference*, pages 124–124, 1993.

[11] G. Vigliensoni and M. M. Wanderley. A quantitative comparison of position trackers for the development of a touch-less musical interface. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 103–108, Ann Arbor, Michigan, 2012.

[12] D. Wessel and M. Wright. Problems and prospects for intimate musical control of computers. *Computer Music Journal*, 26(3):11–22, 2002.

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