Digital Oxymorons

From Ordinary to Expressive Objects Using Tiny Wireless IMUs

Andreas Schlegel
LASALLE College of the Arts (Media Lab), Singapore
andreas.schlegel@lasalle.edu.sg

Cedric Honnet
DataPaulette, France
cedric@datapaulette.org

ABSTRACT

In this paper we discuss the potential of ordinary objects acting as human computer interfaces with an Inertial Measurement Unit, the Twiz, to capture a body's orientation and acceleration. The motivation behind this research is to develop a toolkit that enables end users to quickly prototype custom interfaces for artistic expressions through movement. Through an iterative design process we have enhanced existing technical implementations such as wireless data transfer, battery lifespan, two-way communication and data analysis including machine-learning techniques. We conducted object-making sessions and developed software prototypes for audio and visual feedback. We explored a range of experiments related to visual arts, dance, and music by attaching the Twiz to different types of objects to allow users to carry out impromptu interactions. As a result of this process we have gained a better understand of an objectfis expressive potential whilst capturing and analyzing its movement.

CCS CONCEPTS

• **Human-centered computing** → *User interface toolkits* ; *Visualization toolkits* ; • **Computing methodologies** → *Motion processing* ; • **Applied computing** → *Sound and music computing* ; *Media arts* ; *Performing arts* ;

KEYWORDS

movement data, motion sonification, motion visualization, motion sensing extensions, interactive object, tangible interfaces, multimodal interactive performance, embodied interaction

ACM Reference format:
Andreas Schlegel and Cedric Honnet. 2017. Digital Oxymorons. In *Proceedings of International Conference on Movement and Computing, London, United Kingdom, June 2017 (MOCO'17),* 7 pages.
DOI: 10.475/123_4

1 INTRODUCTION

Computer technologies continue to be more embedded and connected, decrease in size, and become more affordable, accessible and available. Both, the production and the use of physical objects as human computer interfaces have seen an ongoing traction in recent years, especially in areas such as physical computing [14] and the Internet of Things.

One of the features that can be measured in such objects is their motion and in particular, acceleration and orientation. In the following, we discuss an ongoing collaboration between an engineer and an artist. The focus of this collaboration is to develop a range of experiments that explore the potential of artistic expressions by capturing motion with the use of an Inertial Measurement Unit (IMU[1]). Here we make use of the "Tiny Wireless IMU" called the Twiz [5, 18]. By attaching it to ordinary objects we want to discover and define the expressive properties of these objects in the experiments we conduct. With the project we present, we aim to develop a toolkit to prototype IMU-based interfaces through which we seek to find answers to the question: What are the expressive potentialities of ordinary objects when capturing and translating their movement?

[1] IMU with 9 degrees of freedom: 3D accelerometer + 3D gyroscope + 3D magnetometer.

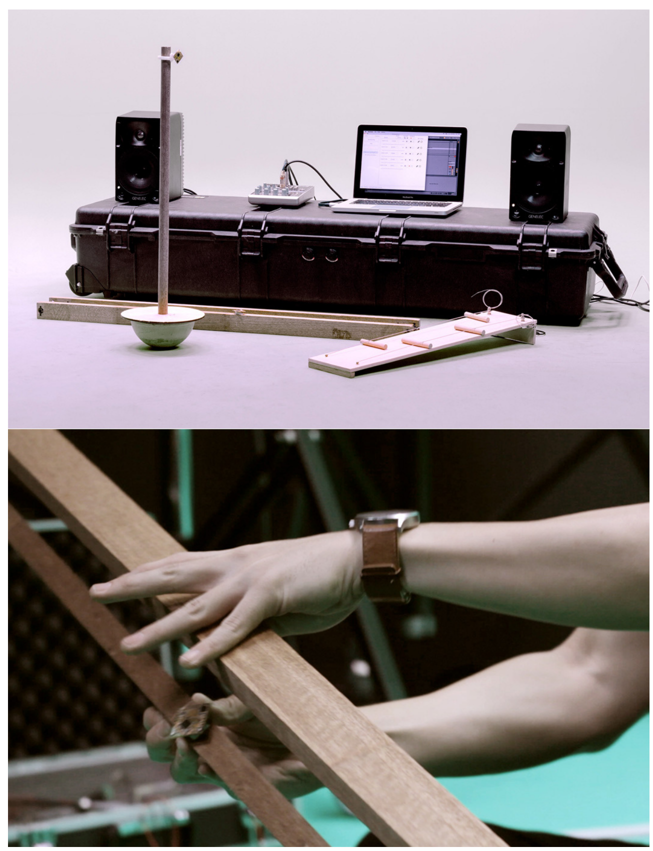

Figure 1: Top: three custom-built ordinary objects. Bottom: a user interacting with a Twiz-equipped object.

DOI: 10.475/123_4

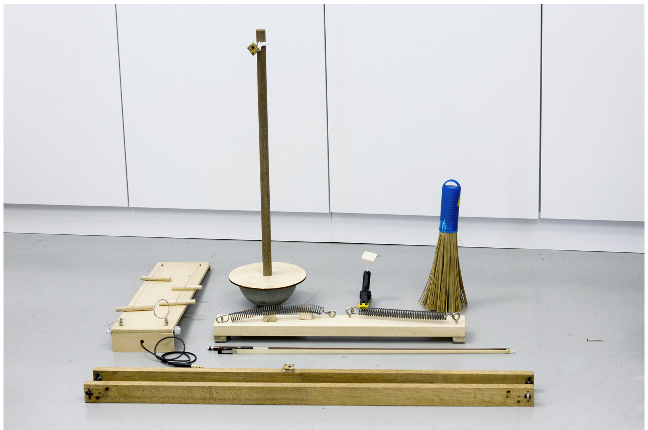

Figure 2: Examples of ordinary objects that we use as motion-sensing extensions.

1.1 Ordinary Objects

Within the context of this project, an ordinary object is understood as a simple physical object that is unexceptional, normal, and everyday, like a chair, a ball, a bow or a paper cup. In the following we will present custom-built objects (see figures 1 and 2) that are created with the intention to be simple, plain, with no special function, which we consider neither very good nor very bad, they are not impressive, reduced to the minimum of necessary parts and easy to understand.

1.2 Motion-Sensing Extensions

Motion-sensing extension is a term we use to describe any physical object that is equipped with a wireless IMU to sense orientation and acceleration of an object's movement (see figure 3). Such objects themselves can operate as motion-sensing proxies for other objects. For example an IMU can be attached to a clamp which itself is attached to a tree's branch. Here the clamp serves as the proxy to sense the tree's movement.

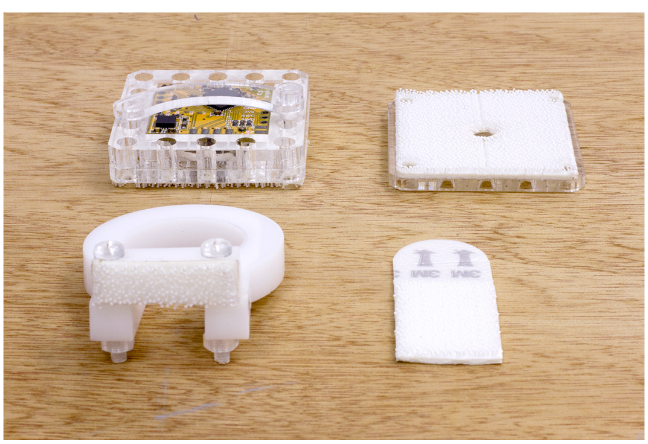

Figure 3: Connectors that are used to attach the Twiz to ordinary objects.

1.3 Expressiveness

Expressiveness or being expressive is an attribute which is often associated with human behavior, the expression of thought and emotion, less so in relation with physical objects. However, expressiveness may be artificially built into an object which may appear differently to different persons and will result in different readings of the expression of an expressive system [8].

2 RELATED WORK

Capturing motion from different types of bodies across artistic and scientific disciplines has a long-standing history. Some notable examples are the early motion captures by photographer Eadweard Muybridge in his work *Horse in Motion* [20], French scientist Etienne-Jules Marey's *chronophotographic gun* [1] which allowed him to capture the movement of animals to study their behavior, neurophysiologist Nikolai Bernstein's work on motion control, or Marcel Duchamp's painting *Nude Descending a Staircase, No. 2* [3].

Artistically we draw inspiration from John Cage's *Water Walk* [2] piece where ordinary objects become musical and performative instruments for this solo television performance. Objects include a bathtub, mechanical fish, iron pipe, rubber duck, and others. The use and the performance of these objects clearly surprised but also amused the audience, and as Laura Paolini notes, "the performance element in this broadcast is important because the audience appreciates the piece more for its performative impact than for the sounds it produces" [15].

Table Recorder by Frederic Gmeiner is a kitchen table that is used as a sound-making object. Interacting with the table through touch to trigger sounds can activate custom-built electronics hidden inside the table. This simple but effective modification transforms the kitchen table into a musical instrument that "sonifies daily actions in a subjective way"[7].

Artificial and living plants are the subjects in *The interactive plant growing* [19] and *Botanicus Interactus* [17] where gestures on plants are used to allow visitors to interact with and observe the audio and visual responses of a plant's virtual counterpart.

In his work Yuri Suzuki often explores the artistic qualities of objects through sound. In *Acoustic Pavilion* [21] visitors are invited "to create their own listening devices [...] to explore how sound evolves through different forms". *AR Music Kit* [22] takes a more technological approach when users create their own musical instruments through simple markers detected by a mobile device.

What these works have in common is the experience of artistic expressions through ordinary objects that we, the authors, find intriguing and inspiring. They seem so simple but very effective at the same time in engaging a broad and diverse range of audiences.

Important to us is to highlight that the focus in the work we are describing is equally important for both the artistic exploration as well as the technical implementation.

Our sensing approach was influenced by very diverse projects. *Siftable* [12] being one of our most inspiring tangible user interfaces. These modular blocks with screens, proximity and motion sensors can be synced wirelessly, but in our case we required more flexibility. The sensor needed to be small in size and lightweight, should attach to objects quickly, and implement a standardized communication protocol for easy connectivity with other electronic devices.

Various sensing techniques have been explored to interact with everyday objects, *IDSense* [9] demonstrates a battery-less identification and localization using UHF RFID but the accuracy didn't fit our need. More specialized motion sensing solutions appear in the literature, for example, the Meta Wear PRO motion sensor [16] satisfied most of our needs but lacked on the affordability and the open-hardware flexibility. The sensor fusion of *x-osc* [13] is known to be one of the best but it was too large in size and is not as power efficient to suit our low energy requirements. On the applicative side, examples of objects for sonification using the *Bela* embedded platform [11] demonstrated an excellent feature in its ultra-low-latency processing of audio and sensor data, but its size, cost and its 1 GHz processor with eliminatory power consumption made it unsuitable.

Considering these technological approaches to measure an object's movement, we chose to work with the Twiz [18] as it best fits our requirements.

3 IMPLEMENTATION

Movement of Things, a collaborative experiment using the Twiz, was conducted in 2015 [5, 18]. Things found in an urban environment including an air vent, washing machine, elevator, trees, amongst others, were augmented with motion sensing extensions and recorded data was then translated into abstract data renderings.

Following this strategy, we propose new motion-sensing extensions and focus on capturing the movement of ordinary objects in real-time with the objective to express recorded data artistically through audio and visual feedback.

We approach this project from two different angles, the technical and the artistic. By doing so there is not only one focus that is addressed in this paper. Throughout the process the focus oscillates between the technical and the artistic which is essential for the authors to note in order to describe the progress in the following.

3.1 Technical description

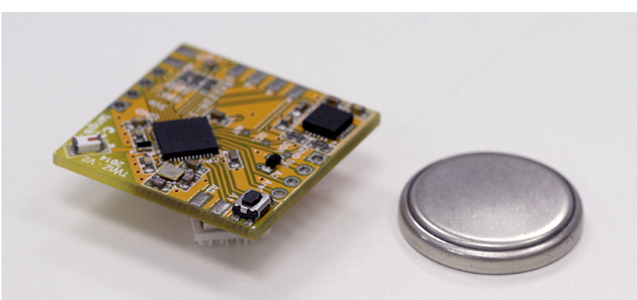

Figure 4: The Twiz next to a CR2032 coin cell battery.

The Twiz was originally created because there was no other wireless motion sensor that was sufficiently affordable, autonomous, and small. It was built with the first micro-controller integrating BLE [2] with an ARM core (nRF51822), and the first 9 DoF [3] IMU (MPU9150). Its low power allows it to run on a coin cell battery (see figure 4), making it thin and easy to reliably power it with new batteries in live performance context. The sensor fusion is performed on board and the data can be transmitted inside BLE's advertising message or through a direct connection with another endpoint. As seen on figure 5, a software application is able to receive Bluetooth data from multiple sensors and forwards the data via OSC [23].

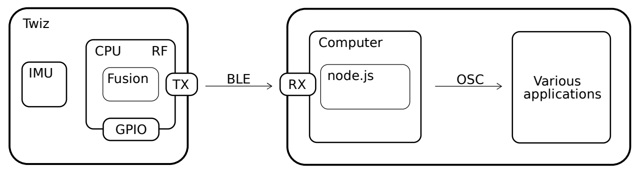

Figure 5: Data flow from physical motion to application: The Twiz (left) measures and processes the raw data, then transmits it over BLE to the computer (right).

3.2 Features and enhancements

The embedded sensor fusion allows extracting the best out of the 9DoF: the gyroscope is very dynamic but not accurate when static, whereas the magnetometer gets a reliable reference but lacks reactivity. Different approaches exist, Kalman based algorithms being more common originally, we used the gradient descent alternative as it proved its significant improvement in computation load [10]. In the following, the sensor orientation refers to the fusion of gyroscope and magnetometer data.

3.2.1 Firmware. We forked the open source firmware to add a new functionalities and make improvements. The original behavior was targeted for short time experimentations and the power consumption was not optimal so we implemented a detector that avoids data transmission when immobile, and we programmed it to enter into sleep mode between two transmissions. For some of our experimentations we considered a full duplex communication to allow actuation reaction in function of a remote processing. We added a bidirectional GPIO access to allow external control for motors or lights, as well as reading from other inputs such as external buttons for example. By upgrading the unidirectional communication to a bidirectional one opens up the option to build a BLE bridge for other micro-controllers such as the Arduino using the RS232 protocol.

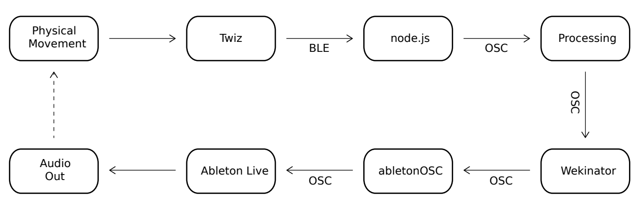

Figure 6: An example for data flowing from physical input to output: a set of processing elements form a pipeline that measures, filters, transmits, recognizes, and use the resulting data to control media.

[2]Bluetooth Low Energy
[3]9 Degrees of Freedom : 3D accelerometer + 3D magnetometer + 3D gyroscope

3.2.2 Software. The sensor's data is sent to a node.js program and forwarded as OSC message so that different programs can use it. Our machine learning expertise being far from advanced, we used intuitive applications such as the Gesture Recognition Toolkit (GRT) [6] or Wekinator [4], and obtained very decent results. Figure 7 shows a recording of a 7 seconds gesture: the Twiz is horizontally on a table with its antenna pointing north (t = 0s - 1.5s), it is then tilted up (around x-axis) by 90 degrees (t = 1.5s - 3.5s), then goes back down to its initial position (t = 3.5s - 6s), and stays still (t = 6s - 7s). This gesture data is processed by Wekinator, which was trained to generate the following control output: channel 2 evolves from 0 to 1, then to 0; channel 4 and 5 do the opposite; channel 1 and 3 almost don't change. These outputs can be used to control music volumes, effects, or light intensity for example.

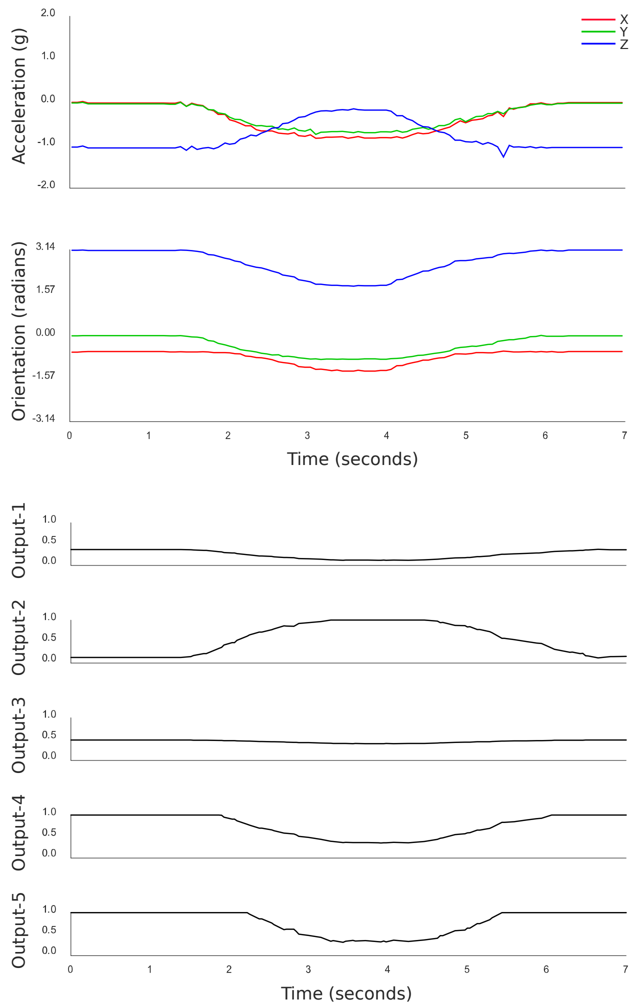

Figure 7: Top: two graphs showing recorded sensor data from a seven seconds gesture. Bottom: Wekinator outputs generated according to the corresponding sensor data.

3.3 Applications and audio-visual feedback

Each software application we built focuses on a different aspect of data processing. A command-line application written in node.js [4] manages multiple Twiz connections over Bluetooth Low Energy and redistributes incoming data as OSC messages to other applications. Each OSC message contains seven arguments, the unique name of the sending Twiz, followed by the x, y and z float values for acceleration and orientation data respectively. A dashboard application (see figure 8) written in Processing [5] allows us to visually monitor incoming data and to forward data to other applications. In one scenario we use the Wekinator software to generate outputs that are fed into AbletonOSC[6], a helper application to route OSC message into Ableton Live to manipulate sound tracks and send audio to a set of speakers (see figure 6).

Another scenario uses an Arduino micro-controller to control the light intensity of an array of led tubes (see figure 13). Data is pass on from our dashboard through a USB-to-Serial connection to the controller. Instead of using an all-in-one solution we distribute tasks such as data transfer, data analysis and artistic expression which allows us to keep our system modular, flexible and extendable.

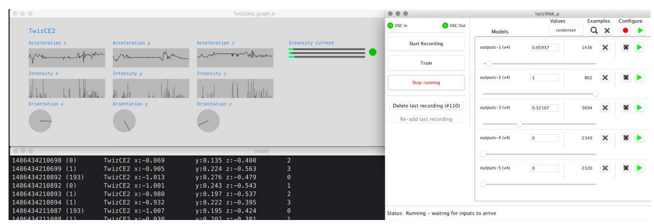

Figure 8: Top-left: a Processing sketch that shows sensors data. Bottom: a node.js application. Right: Wekinator GUI.

3.4 Making objects

Due to the small size of the Twiz we are able to easily attach it to many different types of objects using Velcro, single or double-sided tape, 3D-printed or laser-cut holders. This allows us to quickly prototype user interfaces from custom-built to everyday objects for a range of applications but mostly for artistic expressions. Initially we started using everyday objects as extensions for the Twiz, which worked well as a start. Later we decided to create our own custom-built objects with the intention for each object to focus on characteristics such as swinging, flexing, bowing, plucking, rotating, vibrating, pushing, pulling or bouncing. Working with other artists, we developed a range of objects listed in figure 9.

[4] http://nodejs.org
[5] http://Processing.org
[6] http://github.com/genekogan/ofxAbletonLive

Vibrate	Swing	Rotate	Push	Pull	Pluck	Flex	Bow	Bounce	
		X	X					X	Bouncing Ball
		X		X		X			Flex Wood
X					X		X		Resonating Springs
X					X		X		String Board
	X			X					Suspended Metall Rod
	X	X	X						Swinging Pole

Figure 9: A list of ordinary objects and their interactive characteristics.

The Swinging Pole (see figure 10), a wooden rod attached to a semi-spherical concrete base was built to test out the potential of a swinging object. The Twiz is situated at the top of the pole and is attached to a laser-cut connector (see figure 3). When pushing the pole, the object starts to swing, rotate and after a while comes to a still stand. This action worked well for panning sound for example. Users also started to associate the object with a joystick which allowed them to navigate and explore layered sound textures with one of our applications.

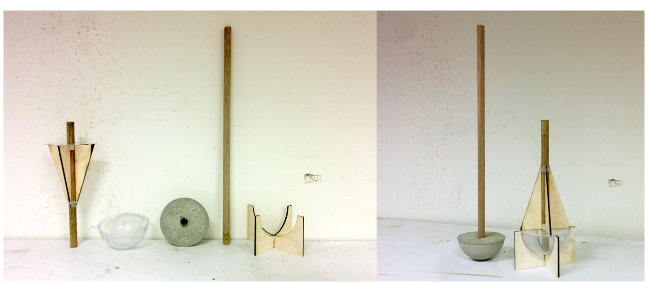

Figure 10: Steps to make the Swinging Pole.

3.5 Working with data

With a focus on translating data in real-time, we have currently identified the following methods measure data that we are interested in: Intensity, orientation, gesture, and action space.

3.5.1 Intensity. The amount of abrupt and fast movements can be measured from the norm of an IMU's acceleration vector, which allows us to calculate the intensity of movement for each axis measured. This method can be used to change the intensity of a lighting system or the volume of an audio track.

3.5.2 Orientation. Using the orientation vector of the Twiz worked well to make an object behave as a wireless potentiometer for example to simulate a fader to control the volume of sound, scrolling through media content such as a video file or scratching an audio track.

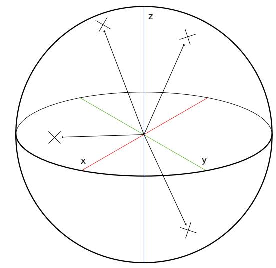

Figure 11: Action space: four markers are positioned along the surface of a sphere with the Twiz at the center of it.

3.5.3 Action space. The third method, the action space, refers to a group of spatial markers (see figure 11) based on which we train neural network models with continuous numeric outputs using the Wekinator software [4]. Both, Wekinator and GRT, are machine-learning libraries, but we found the simplicity of Wekinator more accessible and intuitive to work and prototype with.

We use a supervised learning technique to build a regression model in order to allow multi-dimensional mapping that generates continuous output parameters. After training an action space we are able to use the Twiz to explore a physical space and receive feedback that allows us to identify markers in space and equally important, explore the spaces in between these markers. This technique has been used for examples to control the layering and filtering of sound textures when performed as a musical interfaces or as a performance interface for dancers where audio serves as feedback.

3.5.4 Gesture. To identify a gesture we briefly looked into the GRT and found that for our purposes, to quickly prototype and promptly respond to movement, we want to first focus on interpreting data using the methods intensity and action space and eventually get back to the GRT or other real-time gesture recognition methods in the future.

3.5.5 Outcome. Translating intensity worked well for fast and abrupt actions we found, whereas the action space method qualified better for exploring slower movements. Another feature of the action space method is that data is not interpreted only as true or false and fed back as a binary value but returns in-between values which give the underlying system more variety and allow the user to engage in a gestural and spatial exploration (see figure 12).

4 EXPERIMENTATION

Although both of our backgrounds are from different disciplines, engineering and art, our mutual interest in the other discipline enabled us to find a common ground to discuss the technical and artistic aspects in this project. Furthermore, the environment we were working in allowed us to arrange for ad-hoc user testing since various art practitioners from different disciplines including dance, music and design are located in the same building complex.

We must mention here that our experiments were conducted spontaneously and as such we have not created rich comparable data but have focused on observing the behavior in participants instead.

Figure 12: User experiments with musician and dancers.

4.1 Impromptu interactions

When introducing our project to our participants, we first demonstrate the basic functionality of the Twiz through a visual representation of real-time data on a computer screen. Participants then start testing the Twiz and gain a better understanding of how their actions and gestures influence visual or audio feedback. This quickly turns into playful interactions between the user and the Twiz. In the next step we attach the Twiz to an ordinary object and ask participants to move around and interact with the object freely. Here we use the action space method with audio feedback. We observed that dancers quickly engage in full body movements treating the object as their counterpart or as a way to interact with their fellow dancers often responding to or using the audio feedback as a guide for movements and interactions. Experiments with a musician showed that objects were initially seen as a kind of instrument. Compared to the large and dynamic gestures performed by dancers, gestures were smaller and movements were slower but they were explored with more considered intent as opposed to the more playful actions observed in dancers. In other experiments, participants used our interfaces as controllers for generative visuals or to control the lighting of a light installation (see figure 13).

4.2 Learning from feedback

While developing this project and reflecting on the outcomes of the experiments that we conducted, we found that the learning curve, when interacting with our objects, was gradual and intuitive. Participants quickly engaged with the artificially built in behaviors of an object by exploring movement and responding to the system's feedback naturally. Users were influenced by their own practice as we witnessed in the impromptu interactions of dancers and the musician. In both cases we observed that they were very interested in exploring the characteristics of an object and the cause and effect of their actions.

Sounds for example plays an important role as feedback when using the action space method. Sound that is fed back by the system can be harsh, soft, beautiful, loud, uncomfortable, always based on the positioning of the interface and often requires good attention to detail to recreated a particular sound or silence. Consequently this had an impact on a user's next move and expression, which over time it seemed, was achieved with more ease and confidence. Initial skepticism eventually turned into curiosity and play.

5 CONCLUSION

We have presented the implementation of a motion-sensing technique that uses an Inertial Measurement Unit, the Twiz, which we attach to a range of ordinary objects with the objective to engage in artistic expressions across various disciplines. We have outlined a technical setup to experiment with movement data, which we translate into sound and images using a variety of mostly open source software. The features of the Twiz allow us to quickly prototype interactive scenarios without having to rely on technically demanding setups. Through the experiments we have conducted, we have gained a better understanding of how ordinary objects can be expressive and how an underlying computer system is able to respond to movement data with images and sounds being generated instantly. In these experiments we found that participants engage with our objects intuitively and test an object's boundaries and possibilities in playful ways.

As we continue exploring the expressiveness of ordinary objects, the making of new objects and investigating new options to map our data, we hope to build a promising body of applications that can be organize into a toolkit, an out of the box solution for movement interactions and artistic expressions.

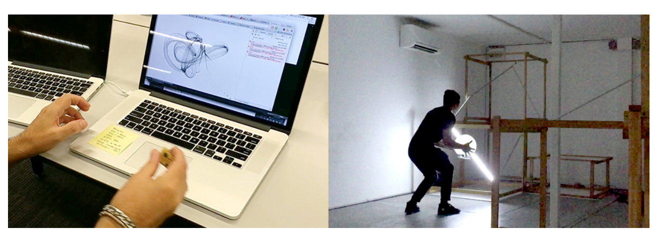

Figure 13: Experiments with visual outcomes for screen and light installation.

ACKNOWLEDGMENTS

The authors would like to thank Hazel Lim, Dhiya Muhammad, Amon Wong and the dance studio at LaSalle College of the Arts, Alexis Polti from Telecom ParisTech for the embedded system guidance, George Gally from Radarboy Studio for the visualization contribution.

REFERENCES

[1] Marta Braun. 1994. *Picturing time: the work of Etienne-Jules Marey (1830-1904).* University of Chicago Press.

[2] John Cage. 1965. *Water walk.* Edition Peters Group, Frankfurt/Main, Leipzig, London, New York.

[3] Marcel Duchamp. 2006. Nude descending a staircase, no. 2. *111847* (2006).

[4] Rebecca Anne Fiebrink. 2011. *Real-time Human Interaction with Supervised Learning Algorithms for Music Composition and Performance.* Ph.D. Dissertation. Princeton University, NJ, United States. Advisor(s) Professor Perry R. Cook. http://dl.acm.org/citation.cfm?id=2125776 AAI3445567.

[5] Rachel Freire, Cedric Honnet, and Paul Strohmeier. 2017. Second Skin: An Exploration of eTextile Stretch Circuits on the Body. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction (TEI '17).* ACM, NY, USA, 653–658. DOI: http://dx.doi.org/10.1145/3024969.3025054

[6] Nicholas Gillian and Joseph A. Paradiso. 2014. The Gesture Recognition Toolkit. *J. Mach. Learn. Res.* (2014). http://dl.acm.org/citation.cfm?id=2627435.2697076

[7] Frederic Gmeiner. 2007. Table Recorder, instrument for the everyday - Retrieved on February 8th, 2017. (2007). http://www.fregment.com/?cat=0&p=7868

[8] D. W. Gotshalk. 1954. Aesthetic Expression. *The Journal of Aesthetics and Art Criticism* 13, 1 (1954), 80–85. http://www.jstor.org/stable/427019

[9] Hanchuan Li, Can Ye, and Alanson P. Sample. 2015. IDSense: A Human Object Interaction Detection System Based on Passive UHF RFID. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15).* ACM, NY, USA, 2555–2564. DOI: http://dx.doi.org/10.1145/2702123.2702178

[10] Sebastian OH Madgwick, Andrew JL Harrison, and Ravi Vaidyanathan. 2011. Estimation of IMU and MARG orientation using a gradient descent algorithm. In *Rehabilitation Robotics (ICORR), 2011 IEEE International Conference on.* IEEE.

[11] Andrew McPherson and Victor Zappi. 2015. An Environment for Submillisecond-Latency Audio and Sensor Processing on BeagleBone Black. In *Audio Engineering Society Convention 138.* http://www.aes.org/e-lib/browse.cfm?elib=17755

[12] David Merrill, Jeevan Kalanithi, and Pattie Maes. 2007. Siftables: Towards Sensor Network User Interfaces. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction (TEI '07).* ACM, NY, USA, 75–78. DOI: http://dx.doi.org/10.1145/1226969.1226984

[13] Thomas Mitchell, Peter Bennett, Sebastian Madgwick, Edward Davies, and Philip Tew. 2016. Tangible Interfaces for Interactive Evolutionary Computation. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16).* ACM, New York, NY, USA, 2609–2616. DOI: http://dx.doi.org/10.1145/2851581.2892405

[14] Dan O'Sullivan and Tom Igoe. 2004. *Physical Computing: Sensing and Controlling the Physical World with Computers.* Course Technology Press, Boston, MA, USA.

[15] Laura Paolini. 2007. John Cage's Secret - Retrieved on February 8th, 2017. (2007). http://www.johncage.org/blog/paolini-cage-eds-editlp.pdf

[16] Katrin Plaumann, Milos Babic, Tobias Drey, Witali Hepting, Daniel Stooß, and Enrico Rukzio. 2016. Towards Improving Touchscreen Input Speed and Accuracy on Smartphones for Tremor Affected Persons. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16).* ACM, NY, USA. DOI: http://dx.doi.org/10.1145/2968219.2971396

[17] Ivan Poupyrev, Philipp Schoessler, Jonas Loh, and Munehiko Sato. 2012. Botanicus Interacticus: Interactive Plants Technology. In *ACM SIGGRAPH 2012 Emerging Technologies (SIGGRAPH '12).* ACM, New York, NY, USA, Article 4, 1 pages. DOI: http://dx.doi.org/10.1145/2343456.2343460

[18] Andreas Schlegel and Cedric Honnet. 2016. Movement of Things Exploring Inertial Motion Sensing When Autonomous, Tiny and Wireless. In *Proceedings of the 3rd International Symposium on Movement and Computing (MOCO '16).* ACM, NY, USA, 47:1–47:2. DOI: http://dx.doi.org/10.1145/2948910.2948916

[19] Christa Sommerer and Laurent Mignonneau. 1993. Interactive plant growing. *Ars Electronica* 93 (1993), 408–414.

[20] Jacob Davis Babcock Stillman, Eadweard Muybridge, and others. 1882. horse in motion as shown by instantaneous photography. (1882).

[21] Yuri Suzuki. 2015. Acoustic Pavilion - Retrieved on February 8th, 2017. (2015). http://yurisuzuki.com/news/acoustic-pavilion

[22] Yuri Suzuki. 2016. AR Music Kit - Retrieved on February 8th, 2017. (2016). http://yurisuzuki.com/news/ar-music-kit

[23] Matthew Wright. 2002. Open Sound Control Specification Version 1.0 - Retrieved on February 8th, 2017. (2002). http://opensoundcontrol.org/spec-1_0