WATERWHEEL PATCH: USING MOBILE DEVICE SENSORS FOR LIVE PARTICIPATION IN AN ONLINE NETWORKED ENVIRONMENT

Ian Winters, independent artist, Berkeley, CA 94703, U.S.A. Email: ian@ianwinters.com
James Cunningham, Igneous Inc., Brisbane, QLD 4103, Australia Email: james@igneous.org.au
Suzon Fuks, Waterwheel & Igneous Inc., Brisbane, QLD 4103, Australia Email: suzon@water-wheel.net

Abstract
This paper documents our current research into using mobile devices to integrate remote physical movement and sound into the online structure of Waterwheel's Tap, allowing participation away from keyboard and mouse based computers. We asked participants in Australia, Indonesia, Europe and the U.S.A. to explore their local waterways or bodies of water. Taking a cue from research using sensors in dance, we are using mobile devices carried by, or attached to, these participants in order to transmit location and motion sensor data, plus live audio, for use as experimental content, feedback and control sources for elements of the Waterwheel Tap while outdoors.

Keywords: Waterwheel, the Tap, collaborative, environment, movement, data visualisation, sonification, mobile device, sensors, Open Sound Control, OSC

Introduction

Since early 2013, we have been developing and researching inexpensive tools for remote physical performers to perform away from keyboard and mouse based computers, with an online audience gathered on Waterwheel's Tap interface (the Tap) [1]. Our research has focused on the use of inbuilt mobile device movement and location sensors (accelerometer, GPS, gyroscope) to send motion data from participants in remote locations, as both a control mechanism, and as a data source to prototype visualisation and sonification methods. Additional components of our research included: evaluating alternative wireless sensor options (essentially any Open Sound Control, or OSC, data source); identifying potential steps for implementing our prototype concepts directly into the Tap; and developing a vocabulary of physical movement '"scores" (meaning, as in dance improvisation, the parameters, motif or images on which to improvise) suitable for generating particular ranges of data according to the sensors used.

Background

Waterwheel is a collaborative online venue for streaming, mixing and sharing media and ideas about water. Initiated by Suzon Fuks and co-founded with design studio Inkahoots, Waterwheel was launched two years ago, and has a growing community of more than eight hundred users – artists, scientists and activists – from around the world, contributing to and creating events such as webinars, symposia, performances and festivals.

The **wheel** on the homepage consists of the latest uploaded media, which are part of the **media centre**, a growing collection of shared water-related audio, images, video, text, spreadsheets and animations uploaded by users. These media items are available for any presentation on the Tap.

The **Fountains** are past and future events, in real places or on the Tap, chronicled on a global timeline-map.

The **Tap** is a video-conferencing and media display system allowing up to six webcams, drawings and media items. Its particularity is that everything can be moved, rotated, scaled, faded or overlaid via a palette of tools. All changes are viewable instantaneously on a single webpage. Users can invite their own 'crew' to present publicly or in private, while audience members can watch a live event with just one click, and comment in a shared type-chat column.

Somatic Considerations

Our previous experiences of embodied interaction in networked online environments in general, and in the Tap in particular, have been via webcams, monitoring the screen, and the use of the keyboard and mouse.

Stemming from these experiences, and in keeping with the environmental focus of the Waterwheel platform, our current research has the following aims related to movement, awareness, the body, and environment:

- to facilitate immersive physical engagement free of the keyboard and mouse, and of looking at screens,
- to enable interaction with remote collaborators without losing connection to one's own body and environment,
- to explore interfaces that enable participants to be in diverse environments – creeks, waterways, landscapes or cities,
- to be able to explore as broad a range of movements as possible – from micro-movements of the body, to travelling, or traversing across landscapes – achievable through the use of a range of movement data sources, scaled through visualisations and sonifications to be either within perceptual range, or contained within a single screen space, and
- that the interface would enable people with mobility impairments to engage with both the projects and the collaborators.

Technical Considerations

Our research process began in January 2013 by establishing several goals for evaluating prospective mechanisms to explore embodied collaborative interaction / creation on the Tap. In addition to the somatic considerations, we identified several key technical requirements:

- our system should be economically and technically accessible to collaborators and participants in a wide range of locations,
- the system should be able to operate on low-bandwidth connections (2G up),
- it should provide a real-time mechanism to collaboratively create / record / interact with movement, compass and location data from all participants,
- the completed system and site integration should be based on extensible and open communication protocol, so that other participants can easily create new tools, and
- that any hardware required be available on the consumer market.

Working with one inherent limitation of mobile devices – that they can only generate information on a single point of the body – instigated an additional research interest, into how to use that data to generate a value for the instantaneous overall movement 'dynamics' or 'quality' as a control source (rather than working with the precise spatial location of individual joints or skeletal tracking, as is more common when working with traditional motion capture systems and 3D depth camera systems such as Primesense or Kinect).

Somatic and Technical Integration

Please reference as: [Author(s)-of-paper] (2013) [Title-of-paper] in Cleland, K., Fisher, L. & Harley, R. (Eds.) *Proceedings of the 19th International Symposium of Electronic Art*, ISEA2013, Sydney. http://ses.library.usyd.edu.au/handle/2123/9475
Page numbering begins at 1 at the start of the paper.

This latter goal, of looking at a movement's dynamic or quality, informed much of our prototyping work, especially in regards to choosing which sensor data to focus on, specifically: looking at changes in the rate, angle, and acceleration of rotation about the axes, of a participant's movement, rather than sensing their absolute position in space. Fundamentally, we are asking: will sensing the body's change in movement tell us more about the instantaneous state of the body than would a more detailed sensing of the body's absolute state or position in space? Recent scholarship (such as Stamatia Portanova's *Moving Without a Body* [2]) explores whether this abstraction of body may be analogous to early twentieth century philosopher Alfred Whitehead's development of the concepts of process philosophy, in which a process or structure (such as quantum position) is the essential descriptor of an 'object', rather than the physical object itself (which is a momentary manifestation of the structure).

In terms of our actual work: in early experimentation we explored various positions of placement of the mobile devices on the body (shin, ankle, sacrum, hand-held, head, chest), and in later experiments we used primarily the head and torso. Driven by this exploration of the structures of change and related ideas of scale, our physical explorations have come to favour sensor placement on the top of the head (usually attached to a helmet) (Fig. 1) as a reliable, easily set-up means to clearly read large and small-scale changes in motion.

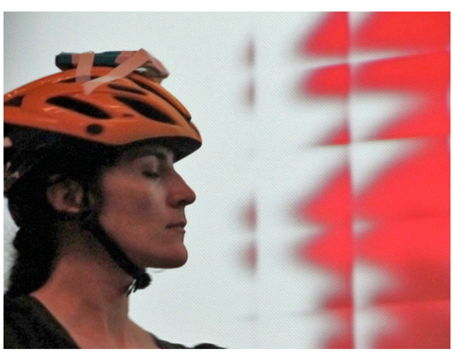

Fig. 1. Volunteer participant ISEA2013 delegate Brisa MP. Photo: Yto Aranda © Yto Aranda and Brisa MP.

We have found that sensor data from mobile devices, thus attached, easily and reliably reads the micro-movements of the head. This kind of motion, as Cunningham found in prior research, when done with focus, and emanating from stillness, brings awareness into one's body. In his essay *Breathing the Walls* [3] Cunningham states:

"When attention to bodily sensation is practiced in day-to-day life, this present moment awareness, or dropping into the moment (…) is also linked to physiological changes. The muscles at the top of my neck relax, the occipital joint becomes more fluid, my breathing relaxes and I'm more aware of it. At the same time, I have access to creativity, playfulness, and a widening sense of possibilities. There is an inner stillness, within which I can sense connection to what is forward and behind, above and below."

The Feldenkrais and Alexander Techniques also aim to loosen the muscles that connect the skull to the spine, and reconfigure patterns-of-connection between head and eye movement, in order to achieve a playful state of physical discovery.

Physical and Software Prototype and Demonstration

System description: The initial prototype system that we developed uses data from the built-in gyroscope, accelerometer (or IMU – Inertial Measurement Unit) and compass of a 3G, or newer, Android mobile device or iPhone. Participants securely mount the mobile devices to a movement centre on their body (sacrum, top of head, or centre of the chest). For prototyping purposes we worked with several commercially distributed apps [4] that transmit sensor data via OSC to a dedicated host IP. The received motion and location data was then processed using a series of high/low-pass filters and complementary filtration [5], implemented in a combination of Max/MSP and Isadora [6] before being used as a source for visualisation, sonification and control.

Three factors drove our decision to use mobile devices rather than custom built sensors:

- with over a billion in use, mobile devices are ubiquitous 'in pocket' technology,
- they are relatively inexpensive and available, and, transmitting limited data over UDP, can work with low-bandwidth internet connections (dial-up, satellite and rural 2G/3G systems), and
- no hardware distribution is required – all of the required 'systems' can be software-based.

Collaborative Data Visualisation and Sonification: For prototype purposes, each participant streamed data from their mobile devices to a central computer using Isadora and Max/MSP to create a variety of live data visualisations; these were then streamed live to the Tap so that in rehearsal, participants could immediately see their motion relative to other collaborators. Building on the work of the prototyping process, we plan to implement an additional 'palette' for the Tap structure: a 'data tab' (Fig. 2) that will allow collaborators to assign data streams to existing Tap tools, stream their own custom visualisations and sonifications (created in Max, Isadora and similar software) to the Tap, and provide tools for collaborative work, transformation and recording of movement data.
This 'data tab' will, in effect, also serve to open the existing Tap structure to interaction with, and control by, any of the tremendous array of interfaces and sensors that utilise the OSC protocol to transmit information. Building on the collaborative and improvisational structure of the existing Tap interface, the 'data tab' would allow participants to:

- combine and manipulate live data of remote participants (motion, compass, location),
- produce collaborative data visualisation,
- record, play back and transform data as part of choreographic, performative or mapping explorations,
- use it as a control source for existing palettes, and
- integrate custom visualisations and sonifications into the Tap via streaming.

A final piece of the prototyping research was to investigate work with transforming sound as a feedback source for non-vision centred remote performance.

The Demonstrations

For the presentation at *ISEA2013* [7] we prototyped how movement data from remote participants could be utilised in a real-time online interface through the use of an Isadora patch.

The remote participants were Russell Milledge and Rebecca Youdell of Bonemap (Cairns, Aus), Mary Armentrout and Marcia Scott (San Francisco, USA), and Kate Genevieve and Evelyn Ficarra (Brighton, UK). ISEA delegate Brisa MP from Santiago, Chile volunteered her participation on the day within the presentation space, and Adhari Donora (Riau, Sumatra, Indonesia) participated in the research on other days.

In keeping with the ideals of Waterwheel, we asked participants to become familiar with, to photograph, and to undertake their physical explorations in proximity to their local creek, waterway or body of water – namely Atika Creek (Cairns), San Francisco Embarcadero (California), Brighton Beach (UK) and the Kampar River (Sumatra).

Telecommunications

We established separate telephone or Skype calls with each remotely participating pair. One member of each pair was tasked with maintaining the call on a mobile device, capturing local sounds, and ensuring their partner could hear the sound of the call. The other was tasked with moving with their mobile device attached to their head or torso, listening to the phone call sound and following the movement "score" of each demo.

Sound as a Means of Feedback

Cross-fading between two sound sources was used as a means of providing sonic feedback to participants about both group and individual movement. Each pair was ascribed a pre-recorded sound loop as 'their' designated sound, and was also transmitting live location sound. The intensity of their motion resulted in a cross-fade between pre-recorded and live sound – with 0 motion correlating to minimum pre-recorded volume / maximum live volume, and vice versa.

The sound that each group received was a combination of all of the groups' live vs. pre-recorded sound mix.

Movement Scores

Each demonstration was characterised by a different movement score on which the remote participants could improvise. The dynamic quality, duration and direction in each score varied, in order to tease out a wide range of data from the sensors, and also to explore different ways of visualising that data. Fine movement sensors such as accelerometers generated data streams rich in detail and nuance. The movement range within each motif was kept minimal, enhancing the possibility for increased embodied awareness, and allowing for participation of people with mobility impairments.

Demo 1: "Compass" was the first movement score, in which the data-sending participants remained in place and rotated their head or torso from one compass setting to another, e.g. from east to west and back again. Timing, range of rotation, speed and repetition of movement was up to their discretion.

Data from the compass was mapped onto a 360-degree panorama of each participant's location (Fig. 3), thus directly tracking the participant's

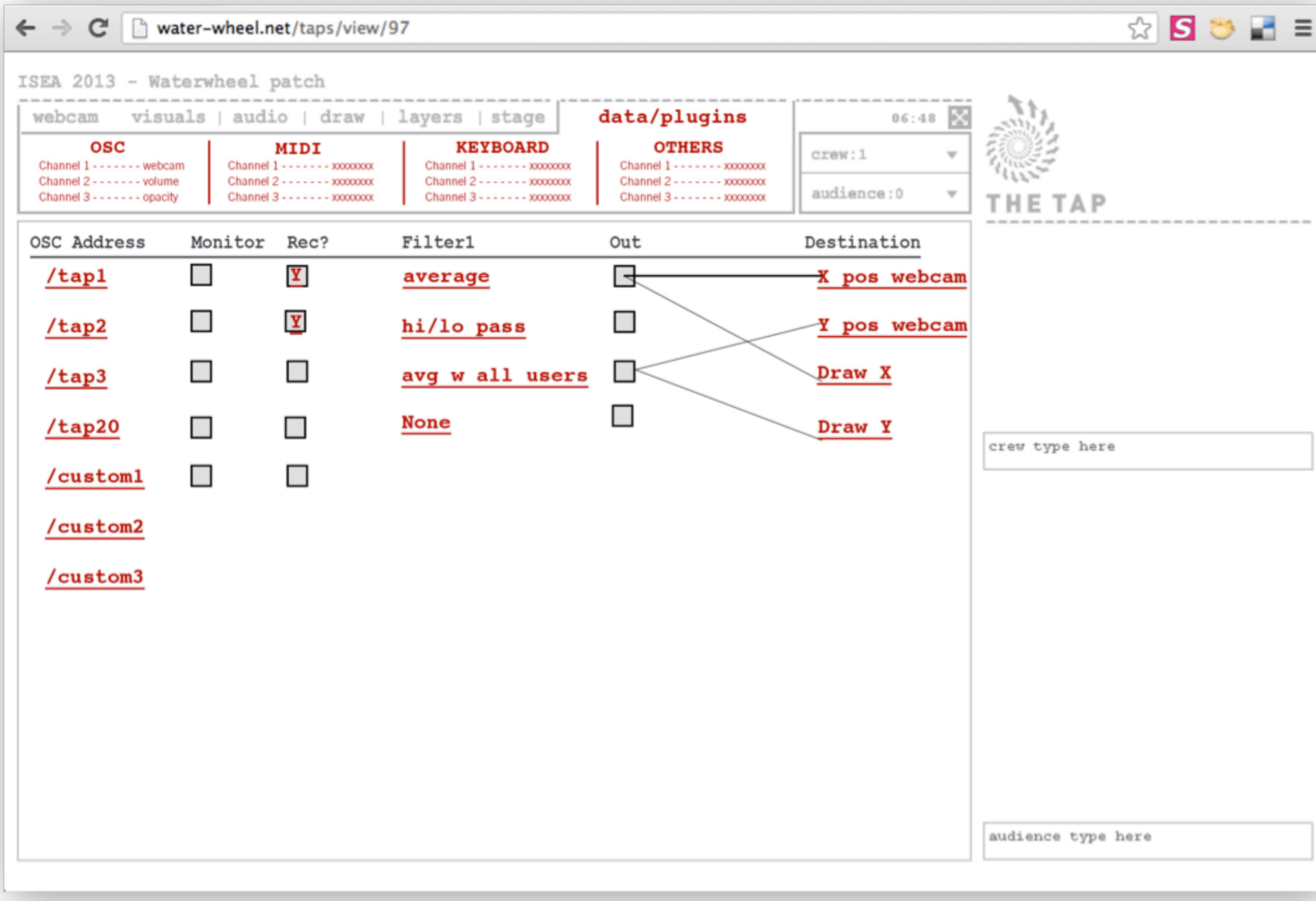

Fig. 2. The proposed "Data tab" showing conceptual arrangement of data inputs. Screengrab © Ian Winters.

orientation in real time. At the same time, the rate of change in each compass reading was calculated to control the balance between the participant's live sound (when still), and 'assigned sound' (when moving).

Demo 2: "Swaying and Stillness" involved minute, gentle side-to-side swaying of the head and torso in any direction, alternating with stillness.

We used gyroscopic data showing change in rotation [8] about the mobile device and participant's body's XYZ axis, which was then mapped onto a simple line drawing visualisation showing the distance between two pairs of XYZ points that are 30 samples apart in time, and then redrawn at a 1 to 5 Hz rate (Fig. 4). This generates a pattern displaying both overall rhythm of the movement, and changes in position.

Demo 3: "Bird" consisted of small, rapid movements in any direction – alternating with "Flowing", which was characterised by smooth continuous movements from one place to another whilst maintaining velocity.

In terms of data, we were exploring the elementary property of accelerometer data, that only change in velocity (i.e. acceleration) is visible, while continuous motion is, in effect, invisible, combined with an incremented '"dead-reckoning" where acceleration in a given direction increments a 3D particle in that direction. (Fig. 5)

Feedback from Remote Participants

Kate Genevieve commented:

"The movements were somatically distinct and interesting for me, and there is something interesting in knowing that the visceral contrasts that I was experiencing were being shared by people in front of the sea in America (...) As a performer I longed to have something that gave me details about where and who the other performers were – perhaps their voices describing where they are would do this well enough, or a webcam at the start."

Rebecca Youdell commented:

"During the rehearsals the focus was on making the transmission of the pairs and the score work, but then at the symposium, the focus switched to making the presentation work for the face to face audience in Sydney, so it became very one way (and) as communication was intermittent and chat not consistent (...) as a pair we felt disconnected from the presentation, but part of the event through transmitting."

This feedback has been valuable in identifying issues to be resolved in any future developments, as outlined in the conclusions below.

Conclusions

The research provided valuable opportunities for, and yielded good progress in, the development of physical scores for interaction using mobile devices, methods of transmitting data from these devices over a variety of networks, prototyping visualisation and sonification of data, trials of connectivity between remote participants via sound feedback, and conceiving the implementation of data feeds into the Tap.

Feedback from the team, the remote participants and *ISEA2013* delegates confirmed interest in these developments. In addition to our already established work with performers in collaborative and networked performance, we found through the conference that a number of people, collecting data related to climate change and environmental issues, are keen to establish a platform that would enable presentation of creative options

Fig. 3. 'Compass' layout showing from top left (Indonesia, map, Brighton, San Francisco, Cairns, Sydney). Screengrab © Ian Winters.

for this data.

Going forward, we have several areas of additional exploration:

- address technical implementation issues and feedback from participants regarding the lack of connectivity between collaborators,
- develop a specific app (for android and iPhone) that provides pre-configured setup for sending OSC data to the Tap, and testing apps and methods of sending OSC data,
- develop a data library or archive as part of the media centre linked to the Tap – to be implemented in partnership with the Inkahoots programming team, and
- further develop movement and sound scores in order to improve both the feeling of connection between remote participants, and how they contribute to a general artwork.

Synchronous vs. Asynchronous Works:

Another important feature of the research to pursue is in the differences between synchronous and asynchronous data-driven works, and the differing qualities of collaborative engagement.

A number of recent artworks using mobile devices, OSC devices and locative media [9] use an asynchronous connection between data collection and visualisation.

Our research seeks synchronous connections by creatively transforming real-time data in the Tap, and providing performative interactivity between crew and live online audience. Projects using this type of interface can stimulate awareness, exchange and debate about embodiment and environmental issues, and, because of its 'liveness', provide agency to people for interaction.

Ultimately we see the Tap data-feed 'plug-in' as a structure that would enable creative and innovative projects by any user of Waterwheel.

References and Notes

1. Access to the Tap is via <HYPERLINK "http://water-wheel.net"http://water-wheel.net>, accessed Oct 23, 2013.

2. Stamatia Portanova, *Moving Without a Body* (MIT Press, 2013).

3. James Cunningham. "Breathing the Walls", Inflexions 6, "Arakawa and Gins" (January 2013). p. 169 <HYPERLINK "http://www.inflexions.org/n6_cunningham.html"http://www.inflexions.org/n6_cunningham.html>, accessed Oct 23, 2013.

4. The applications that we used were: GyrOSC <HYPERLINK "http://www.bitshapesoftware.com/instruments/gyrosc/"http://www.bitshapesoftware.com/instruments/gyrosc/>, accessed Oct 23, 2013; Control <HYPERLINK "http://github.com/charlieroberts/Control"http://github.com/charlieroberts/Control>, accessed Oct 23, 2013; OSCDroid <HYPERLINK "http://www.1mobile.com/oscdroid-507064.html"http://www.1mobile.com/oscdroid-507064.html>, accessed Oct 23, 2013; and TouchOSC <HYPERLINK "http://hexler.net/software/touchosc"http://hexler.net/software/touchosc>, accessed Oct 23, 2013.

5. Motion data was preprocessed using high/low-pass filters to remove outliers, and simplified Kalman type filtration based on implementations by Jan Pieter <HYPERLINK "http://www.pieter-jan.com/node/11"http://www.pieter-jan.com/node/11>, accessed Oct 23, 2013, and Mital A. Gandhi and Lamine Mili**.** **'**Robust Kalman Filter Based on a Generalized Maximum-Likelihood-Type Estimator', IEEE Transactions on Signal Processing, Vol. 58, No. 5, May 2010.

6. Isadora is the graphical programming environment created by Mark Coniglio / Troikatronix See <HYPERLINK "http://troikatronix.com"http://troikatronix.com>, accessed Oct 23, 2013. Max/MSP is a product of Cycling74 software <HYPERLINK "http://cycling74.com"http://cycling74.com>, accessed Oct 23, 2013.

7. Full presentation video documentation is available at <HYPERLINK "http://vimeo.com/68970588"http://vimeo.com/68970588>, accessed Oct 23, 2013.

8. We use "Rotation rate" somewhat loosely as either the calculated composite sensor defined as "rotationRate" in Apple iOS 6 Core Motion framework <HYPERLINK "https://developer.apple.com/library/iOS/navigation/"https://developer.apple.com/library/iOS/navigation/>, accessed Oct 23, 2013, or the similar parameters in the Android "Sensor Manager" class <HYPERLINK "http://developer.android.com/reference/android/hardware/SensorManager.html"http://developer.android.com/reference/android/hardware/SensorManager.html>, accessed Oct 23, 2013.

9. Such as 'Notes for Walking' <HYPERLINK "http://www.creativecultural.com/notesforwalking"http://www.creativecultural.com/notesforwalking>, accessed Oct 23, 2013, utilising preproduced media viewed individually by participants during walks, 'Long Time No See' <HYPERLINK "http://explore.long-time-no-see.org/map"http://explore.long-time-no-see.org/map>, accessed Oct 23, 2013, in which traces of individuals' walks are made visible afterwards, and 'Breathing is Free' <HYPERLINK "http://breathingisfree.net"http://breathingisfree.net>, accessed Oct 23, 2013, a series of visual artworks showing GPS-generated patterns of the artist's runs through cities.

Fig. 4. "Swaying" line drawing score. Screengrab © Ian Winters

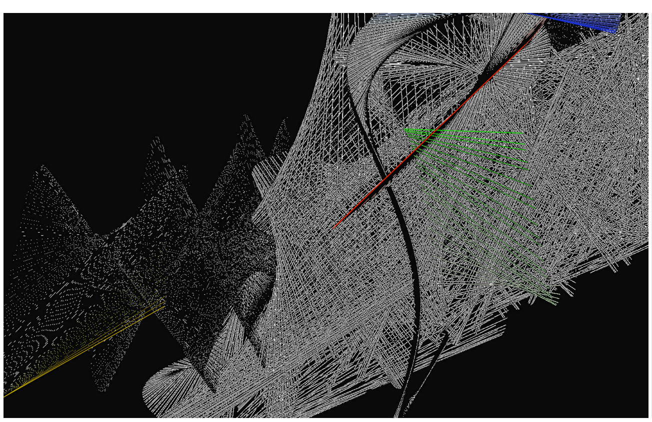

Fig. 5. Each colour of particle is the movement generated by one of the participants. Screengrab © Ian Winters