SLOWNESS, STREAMS, AND NETWORKS IN THE MORE-THAN-HUMAN WORLD: PROTOTYPING AN INTERNET OF THINGS FOR WATER

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https://doi.org/10.34632/jsta.2020.9487

Journal of Science and Technology of the Arts, Vol. 12, n. 3 (2020): pp. 25-44

ABSTRACT

The research project *Wildthings.io* encompasses the development of an experimental set of prototypes for an Internet of Things (IoT) seeking to imagine how an IoT can be built for and with *things* in a more-than-human world. This article discusses the iterative design processes across field explorations and prototyping work that supported the development of the IoT artworks *Moturoa Transmissions* and *Papawai Transmissions*, focussing particularly on slowness as a key method for designing in a more-than-human context, alongside openness and seamfulness. The research outputs seek to explore novel ways of understanding and (re-)connecting with disconnected freshwater streams, their communities and their ecosystems in urban Aotearoa/New Zealand.

Keywords: Networked media; Internet of things; More-than-human; Prototyping; Media art; Slowness.

1. INTRODUCTION

In this article, I discuss the iterative design processes of the research project *Wildthings.io* that first manifested within early prototypical developments as *Moturoa Transmissions* and then concluded in the network installation *Papawai Transmissions*, putting emphasis on how slowness materialised during field explorations and prototyping, leading up to the final public exhibition of these works. With a focus on wai/water, the project set out to imagine novel ways of understanding and (re-)connecting with disconnected streams, their communities and their ecosystems in urban Aotearoa/New Zealand, specifically my place of residence, Te-Whanganui-a-Tara/Wellington. My fieldwork departs from a small stream in my neighbourhood, and fans out into the wider network of local freshwater which has largely disappeared from the cityscape due to urban development. Data collected during fieldwork and lab development has informed the creation of electronic design artefacts to learn how the more-than-human world can inspire the design of networked media.

Departing from the concept of an Internet of Things as a means to give voice to non-human *things*, *wildthings.io* envisioned experimental prototypes for grassroots, community-run digital networks, and DIY electronic devices as artistic interventions. In this article, I address a central question – how can we, as creatives, learn from the more-than-human world when building networked media – through four key sections. First, I engage with an overview of the term *Internet of Things* and present early developments in the field of networked *things*. From here, I consider the development of a *more-than-human* Internet of Things, and how such a concept could de-stabilise the Western anthropocentrism of prevalent IoT approaches, acknowledging seamfulness, openness and slowness as integral parts of my research process. Subsequently, I focus on slowness as an often underacknowledged design approach and the implications on my research trajectory. In the last section, I present a discussion of my research as realised through iterations of the network installations *Moturoa Transmissions* and *Papawai Transmissions*.

2. EARLY THINGS ON THE INTERNET

The term *Internet of Things* originated in 1999 at the Auto-ID Center at Massachusetts Institute of Technology. Kevin Ashton (2009), co-founder and executive of the Auto-ID Center, was the first to use the term in a presentation on improving the efficiency of Procter and Gamble's supply chain management by connecting products via RFID technology to the Internet:

> Adding radio-frequency identification and other sensors to everyday objects will create an Internet of Things, and lay the foundations of a new age of machine perception. (as cited in Santucci, 2009, p. 2)

Journal of Science and Technology of the Arts, Vol. 12, n. 3 (2020): pp. 25-44 https://doi.org/10.34632/jsta.2020.9487

2.1 OF COKE MACHINES, TOASTERS AND COFFEE POTS

The idea of connecting objects to the internet, however, is not entirely new. The first *everyday* object connected to the internet was a Coke machine at the Carnegie Mellon University Computer Science Department. The system, developed in 1982, remotely monitored the out-of-product lights on the machine's push buttons, and published the status of each row of the vending machine on the network so it could be queried through a terminal with the *finger* protocol. Users could retrieve three responses: EMPTY, a timer since the last refill, or COLD in case the last refill was longer than three hours ago (Everhart, 1990).

Another popular early networked object was the *Internet Toaster*, developed by John Romkey in 1990, presented at the Interop Internet Networking show in Las Vegas. The toaster could be controlled remotely via TCP/IP and SNMP (Simple Network Management Protocol). One year after his first demonstration, Romkey added a robotic arm to the setup for loading the appliance with bread slices. In subsequent years, more experimental networked prototypes were presented at the show, such as the *Internet Weather Bear*, outputting weather data via voice synthesis (Malamund, 2000; Stewart, n.d.; Savetz, 1994; Dern, 1992).

The *Trojan Room Coffee Pot* from 1991 is also worth mentioning as it shares a related interest into remote access to beverages, similar to the *Internet Coke Machine*. Developed at the University of Cambridge, England, the project evolved into what is now known to be the first webcam, showing a live image of a filter coffee machine pot. The researchers made the live image available on the World Wide Web with the vision that anyone would be able to watch the coffee machine from anywhere in the world. Surprisingly, the site was hugely popular and allegedly one of the most popular websites at the time.

In sum, these early IoT pieces were built as proofs-of-concept which made an appliance, and consequently the status of a beverage or piece of toast, remotely accessible for more convenient consumption. These early prototypes have inspired more experimental projects and sparked inspiration for networked art. *The Trojan Coffee Pot*, for example, whilst considered the world's first webcam, has also been discussed for its artistic qualities: for example, as "telematic theatre" (Smith, 2005) or as "identic art" (Alexenberg, 2004).

2.2 ARTISTIC IOT ENDEAVOURS

In contrast to the previously discussed networked explorations stands Natalie Jeremijenko's *Live Wire* or *Dangling String*, often referred to as the first Internet of Things artwork (Weiser & Brown, 1996). The piece was developed during an artist residency at Xerox PARC, and described by Weiser and Brown as an eight-foot piece of plastic spaghetti that hangs from a small electric motor mounted on the ceiling, connected to an Ethernet cable. Every bit of information from the lab environment was

https://doi.org/10.34632/jsta.2020.9487

translated into a motor movement so that with more network traffic, the sculpture would start to respond as if alive.

Playful explorations of how everyday objects could be connected to the internet rose substantially during the 1990s, and networked artworks showed a growing tendency to technologically hybridise human and non-human modes of existence. One of the first notable networked art projects, which connected online users with plants, was *TeleGarden* from 1995. The art installation allowed web users to view and interact with a remote garden filled with living plants. Users could plant, water, and monitor the progress of seedlings by controlling an industrial robot arm. Their project thus created a tension between the *natural* living organic environment, and the unnatural robotic arm interacting with it through remote, human commands (Goldberg, K. & Santarromana, J., 2008).

The tensions emergent within this project speak to a broader paradigm in which the category of *human* itself increasingly comes into question. A decentering of the human, and a corresponding shifting of attention towards concerns for the non-human, can be found in a wide variety of recent and current western philosophical lines of thought (Grusin 2015, p.vii). This is a reaction to the predominant anthropocentrism in Western thinking, which some cultures, among them New Zealand Māori, have not adopted into their philosophies. The widespread interest in challenging the traditional divides between humans and non-humans has contributed to a growing push for methods that can work with the distributed knowledges, experiences and values of a more-than-human world.

Human-Computer Interaction (HCI) has shown increasing interest in this decentering, particularly as a "response to concerns about environmental sustainability, technology obsolescence, and consumerism" (Bardzell et al., 2019). Greenhough (2014) claims that natural disasters and an increased spread of zoonotic diseases are urging Western societies to shift their focus away from the human towards the non-human (p.94). The major human impact on earth and atmosphere at a global scale has resulted in the proposal of naming the current geological epoch the "Anthropocene" (Crutzen & Stoermer, 2000). Haraway (2015) demands that it is "our job to make the Anthropocene as short/thin as possible and to cultivate with each other in every way imaginable epochs to come that can replenish refuge" (Haraway, 2015, p.160). Notably, these Anthropocene-related urgencies, among them the looming climate crisis, have been voiced by indigenous peoples long before western discourse has acknowledged them.

3. PROTOTYPING A MORE-THAN-HUMAN IOT

The search for methods involving the decentering of the human aids the establishment of a theoretical grounding for design research that navigates the complex territory of introducing new, more-than-human perspectives to the development of an Internet of Things. My research, as situated in Aotearoa/New Zealand, presented further opportunities

https://doi.org/10.34632/jsta.2020.9487

for engaging in a methodological approach which responds to this call for a diversity of perspectives in design research. As a European born researcher, only having lived in New Zealand for seven years, I need to learn about local, situated knowledges (Haraway, 1988) and perspectives. Working within the context of Aotearoa/New Zealand offered rich learning opportunities when there is already a culture present, where a Māori worldview offers a deep, intricate understanding of *thing* networks.

From a designer's perspective, new, more malleable and open frameworks for approaching research problems are hence emerging, among them post-qualitative research (Lather & St. Pierre, 2013) and non-representational approaches (Vannini, 2015). However, given that they are still in their infancies, these new, cross-cultural traditions face many challenges when trying to weave diverse attributes and non-text focused work into Western academic publishing structures, where they might be described as "messiness" (Law, 2004), or "slowness" (Ulmer, 2017a). These factors, in turn, have become core to my research paradigm where, as I outline below, openness, seamfulness, and slowness have been integral to the development of a networked artwork as part of *Wildthings.io*.

3.1 OPENING UP TO LISTENING TO MORE-THAN-HUMAN VOICES

From the outset of the research, I considered Participatory Design (PD) as an avenue to involve the more-than-human world into the research process as participants. This required unpacking of what participation means in a more-than-human context, and if and how traditional human-centred participatory design methods can provide new perspectives on designing with and for water and connected ecosystems.

> It takes work, and new ways of thinking, and new kinds and methods of openness, to bring substantively new voices into a conversation. (Muller, 2009, p.166)

The opportunities and challenges of adding new voices and perspectives into a design conversation are widely discussed in the field of Participatory Design (see for example Bannon & Ehn 2012; Kensing & Greenbaum 2012). A more-than-human participatory research agenda, as described by Bastian et al. (2017), supports the inclusion of marginalised voices in the research process, and "makes research accountable to those it affects" (Bastian er al., 2017, p.5). Nonetheless, in finding myself working with local communities and ecosystems in an Aotearoa/New Zealand context, it is also vital to acknowledge and incorporate non-western traditions and modes of thought (see Smith, 2012). Blomberg and Karasti (2012) discuss the opportunity to include ethnographic sensibilities into a PD approach, but warn that:

> We should not assume that the tools and techniques of Participatory Design developed for Scandinavian (and other European and North

https://doi.org/10.34632/jsta.2020.9487

> American) audiences will enable multiple voices to define and inform the design when transported to very different traditions. (Blomberg & Karasti, 2012, p.107)

As an artist, designer, coder and researcher taught within Western academia, most of my tools and technologies stem from a Western background. I must avoid a technological colonisation of Aotearoa's more-than-human worlds through my research and the tools I develop.

In the "perhaps the most quoted sentence in the book" (Smith, 2012, p. xi), one which stands central at the opening to the work of *Decolonising Methodologies*, Smith reminds us:

> From the vantage point of the colonised, a position from which I write, and choose to privilege, the term 'research' is inextricably linked to European imperialism and colonialism. The word itself 'research', is probably one of the dirtiest words in the indigenous world's vocabulary." (Smith, 2012, p.1)

I need to be humble and acknowledge the privilege of doing research with and for the water of the streams of Aotearoa/New Zealand. Similarly, I need to scrutinise my background in Open Source Development and keep assessing if and how open sharing of my design research benefits the more-than-human communities it affects. Akama et al. (2020) point out that more-than-human participation is often featured "in reference to human-centred concerns", and further question what it means to "foreground the more-than-human without centring the human as the reason for attention and concern" (Akama et al., 2020, p.2). They argue that as designers,

> [o]ur practice needs to propel us out of current modes of thought, but to resist functionalism when it threatens to close down a welcome for plural ways of knowing, in thinking, in material practice. (Akama et al., 2020, p.9)

An openness to share my process and give the knowledge back to communities who care for their streams implied open licensing and publishing of hardware, software, writings and recordings of my design processes. Whilst it is not within the scope of this article to fully unpack the complexities and tensions which can arise from mobilising *Open* culture into spaces grappling with the implications of decolonisation, emergent work in this field reminds us that as researchers, we must always be critically aware that underlying much *Open discourse* is the assumption of the universality of knowledge systems, often dictated by hegemonic knowledge groups (see for example Adam et al., 2019). I take up this approach to openness in my own work with this caution in mind. Besides the effort to be attentive to more-than-human voices, openness has also been embraced in the design process itself, through the concept of *beautiful seams*, as I discuss in the following section.

https://doi.org/10.34632/jsta.2020.9487

3.2 A NETWORK OF BEAUTIFUL SEAMS

When Mark Weiser (1991) envisioned the computer of the 21st century, he described an environment in which networked computers of various sizes and forms vanish into the background. In his vision, machines resided in the human world and posed no barrier to physical interaction like the then-popular desktop computer:

> Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods. (Weiser, 1991)

In later talks, Weiser (1994; 1995) addressed the misleading concept of seamlessness, and argued for "seamful systems", with "beautiful seams". Weiser also rejected the idea of an interface as a boundary or difference and argued that the unit of design should involve social people, in their environment plus their device (Weiser, 1995, 21). Later, Chalmers & MacColl (2003, p. 1) argued for seamfulness in design and described it accordingly:

> taking account of the finite and physical nature of digital media, seamful design involves deliberately revealing seams to users, and taking advantage of features usually considered as negative or problematic.

Chalmers et al. (2003) pointed out that the revealing of the seams in the infrastructure of Ubiquitous Computing can be an opportunity for user understanding and empowerment. Seams could also be a way towards the creation of more dynamic systems, that are able to adjust to interaction patterns originally not envisioned by the designer.

Figure 1: Testing and debugging the *Papawai Transmissions* network in the field.

Seamlessness in IoT devices is problematic not only in terms of privacy concerns but also in relation to obfuscating functionality to users, preventing understanding of what networked devices really do, at any given point in time. Seamful design tries to

> reveal inevitable seams in ubicomp systems and use them to increase awareness for system infrastructures, their heterogeneous

https://doi.org/10.34632/jsta.2020.9487

> components and otherwise neglected yet useful information within the system. (Broll & Benford, 2005, p. 155).

Inman & Ribes (2019) consider seamful and seamless design as complementary concepts and consider “beautiful seams” as

> a phrase that seems to capture both the spirit of user-friendly, coherent design emphasised by seamlessness and the heterogeneity, contingency, and appropriability of seamful design. (Inman & Ribes, 2019, p.12).

The embracing of seamful design requires slowing down and taking time to acknowledge rough edges as a feature of a design piece. This slowness, however, gives access to discovering qualities of design that might go unnoticed within a fast, optimised development cycle, as I will further discuss in the following section.

4. SLOWNESS IN CREATIVE RESEARCH

> Slowness is a process of unlearning and unsettling what has come before. (Springgay and Truman, 2019, p.15)

As a process of unlearning and unsettling my own perspectives a designer, it was necessary to take time to pay attention to and learn about existing networks before attempting to design new nodes and connections. By advocating for a *Slow Ontology*, Ulmer describes how, in new materialist qualitative scholarship, a more-than-human, entangled approach to research involves the writing of environmental landscapes, as well as writing on/with/through/in aspects of nature (2017a, p.207), calling for more-than-methodologies which “involve material, ecological, and temporal inquiries” (Ulmer, 2017b, p. 53).

An approach to slowness when working with more-than-human ecologies resonates with how Pigott & Lyons (2016) discuss their artistic practice as a

> […] slow attunement and creative ‘listening’. This process involved a distillation of a rhizomic mesh of conversations and encounters, embracing place identity, species, technology and communication. (p.144)

Embracing slowness also afforded time to understand what it means to be a designer in Aotearoa/New Zealand.

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4.1 TIME AND TEMPORALITY

For the following section, I focus on this discourse of *slowness* as a means of mapping the entanglement of this mode within my own research process. Such slowness, in wider design discourse, has responded to *time* and *temporality* as constructs which mediate not only research processes, but the wider material and political contexts in which such work is situated. Here, to draw on Odom et al. (2018), temporality—the state of existing within time—shapes virtually all aspects of how we experience and construct the world around us. By embracing slowness, as I introduce above, I was afforded time to (re)engage with my own positionality as a researcher in the context of Aotearoa/New Zealand. Here slowness, as a conceptual tool, allowed me to pause and reflect on the ongoing flow of research and knowledge production in this setting, both in terms of Indigenous epistemologies, and the more-than-human world which exists beyond the bounds of the university, and indeed anthropocentric constructions of time.

Slowness, as a design tool, has emerged from a wider research trajectory which emphasises embracing different experiences of time. Here, to again mention Odom et. al. (2018), turning to *slowness* as a component in the design process can support experiences that include moments of mental rest and solitude (Odom et al, 2018, p.384). Moreover, as they note, another area of work has investigated temporality and slowness as different ways of framing the design of interactive systems themselves, where slowness has also been applied in design efforts to support experiences of anticipation, social connection, and longer-term relations with everyday computational objects (Odom et al, 2018, p.384). Moreover, embracing not only different experiences of time, but different *perspectives* on time, can expand the theoretical realm of design methodology in order to acknowledge the ways in which time itself functions as a mode of colonial knowledge (Rifkin, 2017).

If time is then the medium through which an "interactive dialogue between a human and computer begins, unfolds, and resolves" (Odom et al., 2018, p.384), turning our attention towards examining different perspectives of time can equip designers with a means through which to critically (re)engage with such beginnings and resolutions, and indeed the temporal nuances entrenched within. In looking to extant research in this area, Lindley (2015) and Pschetz (2015) envision time as always already socially entangled and relational, highlighting the need for alternative expressions of temporality in design. Taylor et al. (2017) further address the decolonising potential of such approaches, through a cross-cultural design project that emphasises time from an Australian Aboriginal community's perspective. Here the designers propose the concept of the *situational when*, that emphasises an approach to understanding time in interface design "not as a point on a calendar or clock, but as a set of converging circumstances that constitute 'the time for happenings to take place" (2017, p.6461). Attention to the "situational when", they argue,

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> opens up new possibilities for design that put greater emphasis on the social and relational aspects of time, the situational insights embodied in local narratives, and the tangible (e.g. people) and intangible (e.g. energy) circumstances that together make up the 'right' time. (2017, p.6461).

Such research highlights the need for new design methods to embrace the diversity and fluidity of *time*, as well as the complexity in designing in timeframes that may well expand beyond the lifetime of the design team itself (Odom et al., 2018, p. 384). Researchers have also proposed different themes, such as narrative time and ephemerality as resources for design. Returning to Taylor et al.'s *situational when*, the process of *slowing down* to attend to the situation has also been a rich vein of design research. Whatmore and Landstrom (in Noorani & Brigstocke, 2018, p. 24), for example, contrasted a conventional participatory ethos of empowering local *people* with an ethos of empowering the *situation*, where the aim is to *force thought* in those affected by it and to *slow down* the reasoning. The effect of embracing slowness, in this instance, has direct implications for my own research journey. To quote from Noorani and Brigstocke,

> Through intentionally building stages and spaces for the intermingling of human and non-human agencies, and slowing practices down, hybrid forums of knowledge and expertise can offer innovative practical and political responses. (2018, p. 24).

4.2 PAYING ATTENTION TO SLOWNESS AS PART OF THE DESIGN PROCESS

While quick iterations of design outputs would appear as a productive way of pushing the progress of a design work further, considerations of the impact of my research, such as introducing networked technology into the more-than-human worlds of local freshwaters, slowed my research progress down from an academic perspective. However, this slowness allowed a richer and deeper engagement with concepts from a Te Ao Māori (the Māori world), to get a glimpse of a future of being able to contribute to research on the interface between science and indigenous knowledge (as described by Durie, 2004).

As part of the development, slowness, first mistaken as a hindrance to my research progress, then allowed me to take the time needed to listen and connect to the field, and allowed early, seemingly unproductive activities, to slowly reappear as productive outcomes in my design interventions. For example, early exploratory walks were primarily aimed at testing prototypes of a DIY hydrophone, that never ended up being used as part of a final installation. These walks later evolved into field explorations with a focus on listening. Eventually I used some of the resulting field recordings as aural backdrop during prototyping and

https://doi.org/10.34632/jsta.2020.9487

evaluation activities in the electronics lab. I was reminded here of the work of Hallnäs & Redström (2001), who argue that a basic principle of slow technology is to *amplify the presence* of things to make them into something more than just a silent tool for fast access to something else (2001, p.209).

Given the experiences presented here, I frame my own approach and response to *slowness* in line with Hallnäs & Redström (2001, p.210), who propose two basic guidelines for slow technology:

1. focus on slowness of appearance (materialisation, manifestation) and presence – the slow materialisation and design presence of form.
2. focus on aesthetics of material and use simple basic tools of modern technology – the clear and simple design presence of material.

Embracing these principles as part of the field explorations required me to slow down, and take the time to acknowledge the rough edges encountered and later created during my field work. By aiming to create complete recordings and documentation of my research, I overlooked that the tending of recording equipment would inhibit my ability to employ my own senses for being in the field. Hence, I later conducted several un-documented walks to the sites, in which I tried to pay attention to the stream, instead of focussing on my recording devices. During the first field explorations, the process of walking and conversing meandered between slow movements and immersions.

The lens of slowness also afforded more time to understand what it means to be a designer in Aotearoa/New Zealand. Slowness allowed me to pause and take the time to acknowledge that research and knowledge production have been part on this land centuries before the establishment of the university and academia. Slowness may also be ascribed to a crucial latency phenomenon, where intertwined cultural perspectives must be addressed in all their complexity. The inclusion of more-than-human concerns into research methodologies have been central to Te Ao Māori and Mātauranga Māori (the Māori way of engaging with the world) long before academia started to turn attention away from anthropocentrism.

Figure 2: *Moturoa Transmissions* installation showing temperature sensor probe suspended left, ec-sensor attached to fencepost on the right and the base station further in the background

https://doi.org/10.34632/jsta.2020.9487

5. *WILDTHINGS.IO* – AN INTERNET OF WATER

As part of my creative research with Papawai Stream and Moturoa Stream in Pōneke/Wellington, I developed experimental prototypes for a more-than-human IoT network. These consist of a range of DIY electronic nodes as artistic interventions, collectively created and published as *Wildthings.io*. The installations *Moturoa Transmissions* and *Papapwai Transmissions* contain a collection of low-cost, Internet of Things network prototypes for engaging with local stream environments. The stand-alone Wi-Fi networks, installed at streams in Pōneke/Wellington, consist of several modular DIY Wi-Fi nodes that capture, visualise, and sonify data such as electric conductivity, temperature, and turbidity. The networks aided the imagination of novel ways of (re-)connecting with disconnected waters and their more-than-human ecosystems.

Prototypes for the network were developed in response to field immersions, walking conversations, lab prototyping, test installations and exhibitions, presentations, and publications. From the outset of the prototyping process, I developed tentative parameters for evaluating my design outputs, ranging across theoretical, artistic and technical considerations. While I started with a larger, and more detailed and specific set of parameters to work with, four categories expressed the character of my research journey across data collection, generative design research and evaluation. At first glance, openness, seamfulness and slowness appear as shortcomings or hindrances to creative development – especially from the perspective of a technology industry where quick development cycles, seamless solutions and prototype development towards exit strategies are idealised. In this final section, I introduce the iterative development process of the IoT artworks as part of Wildthings.io and conclude with a discussion of highlighted methods.

5.1 PROTOTYPING QUICK ITERATIONS: *MOTUROA TRANSMISSIONS*

The first publicly exhibited iteration of *wildthings.io* was installed as part of the Brooklyn Arts Trail at Moturoa Stream in Pōneke/Wellington under the title *Motuora Transmissions*. The installation was centered around one Raspberry Pi single-board computer with an external USB antenna serving a local Wi-Fi network and acting as an MQTT broker for handling communication between the Wi-Fi various sensor nodes. The nodes were built with Wemos D1 microcontroller boards supplemented by custom hardware designed to monitor the stream site with a range of environmental sensors, a mix of off-the-shelf shields and DIY sensor solutions based on recycled materials. Located at one of the entrances by the park, the artwork greeted visitors with the following artist statement:

https://doi.org/10.34632/jsta.2020.9487

> A networked series of interventions in the surrounding environment of Moturoa Stream that senses and monitors change in a range of variables, such as temperature, humidity and conductivity. Together the stations enter a conversation beyond their mere weather-reflective qualities and given structure of land, water and its human and non-human encounters to form a visually engaging addition to the ecosystem in which they are situated.

The piece was installed close to a secondary entrance of Central Park, where Moturoa Stream is not directly visible but – unbeknownst to many locals – emerging from an underground pipe. Hidden from sight behind thick foliage (see Figure 2), the stream water cascades from the pipe outlet into a small plunge pool, before making its way down through the park before being piped underground again. The selected location intended to highlight the transition the water made between the ontological categories of *stormwater* and *stream*. However, the site also obfuscated an apparent connection between the exhibited electronic artefacts and the stream, without providing further context to an audience.

The art trail ran for three consecutive days and the artwork was operating only during daytime hours so it could be disassembled at the end of the day for recharging the batteries overnight. This not only allowed some time to do any required repair work, improvement or cleaning of the nodes but also provided an opportunity to quickly develop new components from prepared spare parts.

Figure 3: Plastic bottles used to collect stream water samples for testing sensors in the electronics lab.

While the schedule of the public art event pushed the development of the project significantly forward within a few weeks, the compressed timeframe of quick iterations developed overnight based on feedback from the audience came with a few drawbacks. Access to the stream had significantly changed between the exhibition and earlier location visits, with flax bushes and other vegetation overgrowing the site and the chirping of cicadas dominating the soundscape. Having some of the artefacts tested as part of the network in the field for the first time during the exhibition was stressful and demanded on-location debugging and adjustments. As a result, some of these field updates were not appropriately documented in the online code repository due to the lack of Internet access on location.

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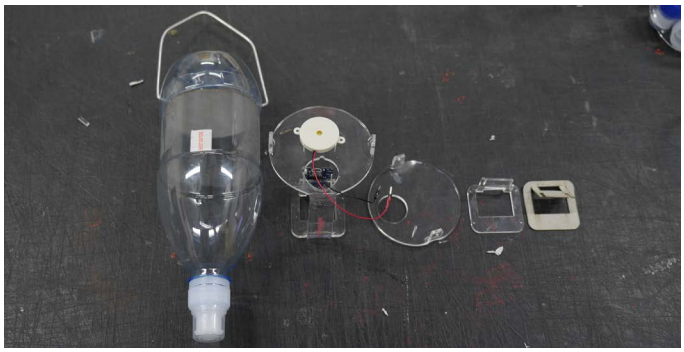

Figure 4: First prototype of the plastic bottle enclosure with iterations of the laser-cut acrylic inlays holding componentry and battery in place.

Initial challenges for the exhibit included outdoor-proofing the installation and providing reliable power to all nodes. The setup needed to be suitable for exhibition across multiple days under variable weather conditions, protecting components and circuitry against more-than-human forces such as moisture, wind and heat. The exhibited design re-used water bottles initially needed for collecting stream samples for testing early sensor iterations nodes in the lab, adapted to house all circuitry and componentry that needed to stay out of the water. The transparent casing additionally gives an audience visual access to all componentry and reveals the processes and connections that went into the assembly of the hardware.

The repurposing of used water bottles as outdoor-proof project enclosures, instead of manufacturing new materials, resonated with a low-cost and low-impact approach to prototyping and significantly extended the usage period of these single-use materials. The bottle enclosure design also linked back to a range of discarded bottles I encountered in the exploratory walks as part of my fieldwork, where I discovered recently disposed of soda bottles left beside the stream banks, and older ones slowly emerging from muddy stream beds after heavy rainfall. A disadvantage of the material, however, was that it slowly degenerated and cracked over time from continuous de-assembling and re-assembling of the nodes for charging and maintenance.

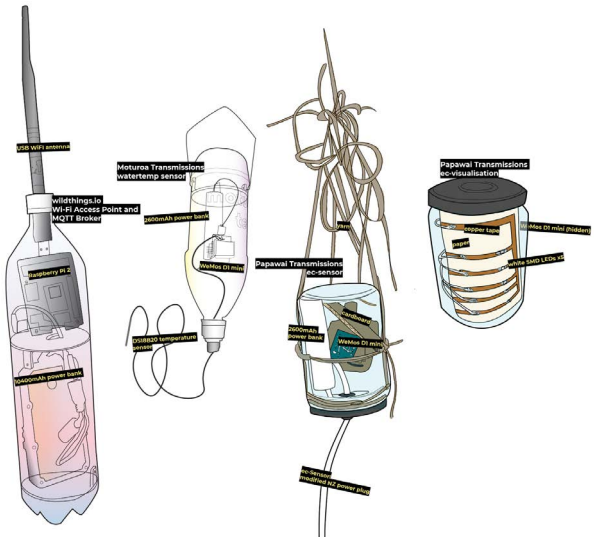

Figure 5: Iterations of networked prototypes showing the Wi-Fi hub and MQTT broker (1), the design of the Moturoa Transmissions water temperature sensor (2), and the Papawai Transmission ec-sensor(3) and ec-visualisation (4) probes.

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Overall, despite being the result of a quick development cycle, the installation of the prototypes as part of a public art event provided better understanding of the limitations of a networked artwork installed in a stream environment and yielded material to depart from for further iterations of the piece, cumulating in the work *Papawai Transmissions*, which I introduce in the next section.

5.2 SLOWING DOWN AND TAKING TIME: PAPAWAI TRANSMISSIONS

The development of *Papawai Transmissions* was set at a stream in a different suburb of Pōneke/Wellington, and was based on previous design outputs and outcomes of *Moturoa Transmissions*. With no fixed exhibition schedule, the oscillations between fieldwork and lab development provided more opportunities for experimentation and productive failure. While the basic network design with the Raspberry Pi hub node at heart remained the same, a variety of additional nodes were developed and updated in response to feedback from invited participants, among them individuals from local DIY electronics, arts, and stream restoration community groups. Modified glass jars replaced outworn bottle enclosures, and previously laser-cut acrylic inlays (see Figure 4) were simplified in the form of paper and cardboard pieces.

Figure 6: Papawai Stream installation showing visualisation node for electric conductivity in the front and sensors installed in the back

A notable addition to the *Papawai Transmissions* network was the installation of bespoke nodes that would visualise incoming sensor data through LEDs, translating changes to the stream environment into light, or sonify stream data, translating changes to the environment into sound. While sensor nodes would be placed beside the stream, the outputting nodes could be placed closer to accessible paths at viewable height for an audience.

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The network was designed to connect a human audience in various ways to the streams, which were reflective of the kaupapa, or purpose of the project, through slowness, seamfulness and openness. First, the installation could be encountered in the wild and investigated by an audience at their own pace. Simple labels on the nodes would help identify what data a node was measuring or representing. Second, the installation was also aimed at an audience who would be invited to help install the work and learn more about the technology involved, while spending time with the nodes and the stream in the wild. Audience feedback also indicated the interest in self-guided walks and installations of probes along the stream. This approach opens possibilities of adding a field notebook to the artwork, in which human participants can add their own narratives to the sensor data by recording their observations, e.g. by adding paper notes to the kit which could be included in the project enclosures, providing a layer of data outside of the digital network functionality. Finally, the online repository contains code and schematics of all *wildthings.io* nodes, and invites developers to use the setup as is, or modify the work to suit their own stream environments and re-share with their communities.

6. CONCLUSION

This article has discussed how, through embracing methods of openness, seamfulness, and particularly slowness, the project *Wildthings.io* has sought to respond to the question of how we, as a design community, can learn from the more-than-human world when building networked media. Via the development of experimental prototypes for grassroots, community-run digital networks, and DIY electronic devices as artistic interventions, the project gave way for further investigation how slow development cycles of networked technology can open new avenues for understanding designing within and for more-than-human world.

Designing an Internet of Things for wai/water requires patience, and the acknowledgement that the decentering of the human within a human-led design process needs slow and careful attunement to the more-than-human world. Spending time with the stream during exploratory fieldwork first, and later during the testing and installation of prototypes provided valuable observations on how the work plugs into the existing networks around the freshwater. Paying attention to the non-human animals, plants and rocks that it stands in symbiotic relationship with, besides noticing human interventions in these relationships in the form of pipes and culverts, or discarded glass and plastic, as well as taking the time to learn about the wairua/spirit of the place that extends beyond measurable data, provided rich insights to be considered for further iterations of this work.

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ACKOWLEDGEMENTS

First of all, I would like to thank all participants who generously contributed their time and knowledges to this research project. Further, I would like to express my sincere gratitude to my doctoral supervisors Dr. Anne Galloway and Professor Sally Jane Norman, for their continuous encouragement, support and thoughtful advice throughout my research journey. I am grateful to my colleagues, especially research coordinator Dr. Catherine Hoad, for engaging in and providing critical feedback on my work. I would like to thank the anonymous reviewers of this article who provided valuable comments and helpful suggestions to improve this work.

Article received on 09/09/2020 and accepted on 06/11/2020.