Mobile Computer Music for Percussionists

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Contents

Abstract

This thesis traces the development of a number of mobile computer music systems and their use in ensemble percussion performances. The research is motivated by the challenges of working with laptop based computer music systems in ensemble situations. The aims were to develop elegant, portable, and flexible computer music tools, to make these tools accessible to other percussionists, and to discover the opportunities that they enable in performance practice.

These aims have been explored through three musical projects for percussion and *Apple*'s *iOS* devices: *Nordlig Vinter*, a suite of duo compositions; and two collaborative works, *3p3p* and *Snow Music* developed together with two other percussionists.

Articulated from a performer's perspective, this artistic research examines a number of software frameworks for developing mobile computer music applications. The development, rehearsal process and performances of the musical projects have been documented with video and audio recordings.

An ethnographic investigation of this data has given insight into the limitations and affordances of mobile computer music devices in a variety of performance contexts. All of the projects implemented elegant computer music setups and the limited visual interfaces of the mobile devices demanded simple but clear interface design. In *Snow Music* in particular, "percussive" interaction with the mobile devices along with an improvised performance practice contributed to a collaborative development cycle. This process revealed some of the limits of expression with the computer sounds used and led to a very successful series of performance outcomes.

Keywords:

percussion, mobile computer music, *Apple iOS*, collaborative performance practice, ethnography, artistic research.

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Terminology

The following is a list of terms and abbreviations from computer music and programming that are used in this thesis.

iOS	The operating system (software) that runs on Apple's iPhone, iPad and iPod touch.
mobile computing devices	A new category of portable electronic devices featuring powerful computers such as *Apple*'s *iPhone* and *iPad*. Of interest to this thesis is mobile devices' ability to run advanced computer music software.
Objective-C	A modern programming language that is used for desktop and mobile application development on *Apple* computers running *OS X* and *iOS*
OS X	The operating system (software) that runs on modern *Apple* computers (but not *Apple*'s mobile computing devices).
patch	A term for a computer music program written in *Pure Data* (or *Max/MSP*). A patch can function as a composition, playing sounds in a predefined order, or as an instrument, where sounds are produced based on user interactions or as a combination of composition and instrument.
Pd	Short for "*Pure Data*"
Pure Data	A computer music programming language developed by Miller Puckette (1996). *Pure Data* allows computer music programs to be constructed

	visually in a graphical programming environment. *Pure Data* is closely related to the computer music language *Max/MSP*.
RjDj	A commercially developed *iPhone* app for distributing reactive and interactive computer music compositions. Composition are created as Pd patches that can be uploaded to the iPhone app over a network connection or through the *RjDj* website: `rjdj.me`
scene	The name for interactive computer music compositions in the *RjDj* app. An *RjDj* scene encapsulates a *Pure Data* patch, images for display in *RjDj*'s visual interface and bibliographic information about the the composition.
XCode	An Integrated Development Environment (IDE), that is, a suite of tools for programming and designing software. *Xcode* is distributed by *Apple* for developing applications for *OS X* and *iOS*.

1 Introduction

This thesis traces the development of a number of mobile computer music systems and their use in ensemble percussion performances. My goal with this project is to develop elegant, portable and flexible computer music tools for live performance. I also aim to make these tools accessible to other percussionists and to discover the opportunities they enable in performance practice.

In 2010, I moved to Piteå from Canberra, Australia to continue my education in percussion and improvisation with a special percussion ensemble, *Ensemble Evolution*[1]. Together with with Maria Finkelmeier and Jacob Remington, this percussion trio was formed to bridge a gap between university and professional percussion groups. This experience was vastly different from any other project I had worked on, even as a classical percussion student in Canberra. In particular, it became clear to me that I needed new computer music tools to complement percussion instruments in my work as a music creator, collaborator and performer.

1.1 The Problem with Laptop Music

In the years previously I had been heavily involved in creating interactive media and computer music performances using both acoustic and electronic percussion instruments along with completely computer based music making tools. The potential in computer music to augment, warp and experiment with acoustic sounds always seemed a natural fit with percussion performance practice. I was also fascinated with the unique interactions that were possible with computers and I collaborated on works that forged new connections between sound, visuals, and movement.

[1]Ensemble Evolution can be found on the web at: `http://www.ensemble-evolution.com`

In these performances I would typically use my laptop with some "heavy" professional software such as *Apple's Mainstage* or *Ableton Live* as well as a programmable computer music environment like *SuperCollider* (McCartney, 2002) or *Pure Data* (Puckette, 1996). This kind of setup was extremely flexible and powerful for creating music and interacting with electronic instruments and other sources of input, such as data sent from projected visualisations or sensors tracking the positions of members of the audience.

The downsides of this setup started to occur to me soon after I had started performing in Piteå with *Ensemble Evolution*. Some of the main goals for our group were to travel frequently, to share our ideas, and to work together on lots of different composition and improvisation projects. All of these goals were in some way incompatible with how I was using computers in performance.

The first problem with my laptop system was that it was heavy and difficult to set up. In our constantly changing studio it became a burden to use and it was annoying to travel with, even on relatively short trips between Piteå and Stockholm. When we did make it to a stage, it was hard to find a place among all the percussion equipment to set up a laptop and run a power cord and audio cables to it. My previous works often had days of setup and rehearsal time and multiple performances in the same space so this hadn't been an issue.

The second problem was that it wasn't easy to "share" my computer music ideas with the others in the group since they had only some knowledge about computer audio production and no skills and little interest in computer music programming. In other projects, my collaborators had been experienced or at least informed about computer based music and art creation.

The third problem was that working on computer music is a solitary task, like most effective computer programming, and entirely unlike rehearsing and improvising. My previous projects with computer had worked best with significant preparation time between rehearsals for composition and programming. In Piteå, we often worked on projects together everyday. The pace and intensity of this group work, while extremely beneficial for my percussion playing, excluded the computer based aspects of my work.

These problems were only some of the reasons that my computer music work essentially stalled when starting this new course in Piteå, the other being that I wanted to focus on vibraphone and marimba improvisation with my teacher, Anders Åstrand, a specialist in that field. However, I didn't completely abandon computer music and it remained a central component of my approach to composition even though I wasn't relying on it as much as I had previously.

As far as I could see, mobile computer music devices, that is, computer music software running on mobile phones and tablet computers, had the potential to solve many of these problems. These devices are smaller, lighter, and more limited in function and so easier to to set up than laptops.

These devices use touch interfaces that provide less precision than a mouse and keyboard and are normally used with one "app" at a time. These limitations encouraged simpler and more focussed interactions in mobile apps. Music apps tended towards emulating a single instrument, one kind of synthesiser perhaps, rather than a whole "virtual studio". This kind of computer music application, I thought, could be easier to share with percussionists who are used to combining simple instruments into multi-instrument setups for performance.

1.2 New Inspirations

I had first started to think about how I could use mobile computer music devices at a conference, "New Interfaces for Musical Expression"[2] held in Sydney in 2010. This conference is one of the main academic outlets for computer music students, academics and enthusiasts and often features large contingents from the world's computer music centres: Stanford, Princeton, UC San Diego and Santa Barbara from the USA, McGill from Canada, IRCAM[3] and STEIM[4] from Europe.

At this year's conference, "mobile music" had become a hot topic. *Apple*'s *iPhone* had reached a critical mass of ownership among computer music geeks and the *iPad* had just been released (and I had one!). Stanford's Center for Computer Research in Music and Acoustics[5] had a "mobile phone orchestra" using these cool new toys and lots of clever programming and network tricks in their performance. I attended an *iPhone* programming workshop run by the Stanford graduate students and learned a lot about the potential for making music with *iPhones* and *iPads*. Despite the technical feats these researchers had achieved, it wasn't the "Mobile Phone Orchestra" at NIME that really inspired me.

In the evenings of the NIME conference, there were gigs in a backstreet gallery in Sydney's inner suburbs. After some reasonably boring synth

[2]International Conference for New Interfaces for Musical Expression: `http://www.nime.org/`

[3]Institut de Recherche et Coordination Acoustique/Musique: `http://www.ircam.fr/`

[4]Studio for Electro-Instrumental Music: `http://www.steim.org`

[5]Stanford CCRMA: `ccrma.stanford.edu`

music, a man stood up with an *iPhone* in each hand, each plugged into a guitar volume pedal, and improvised wildly and masterfully for 40 minutes with electronic textures, processed voices and other undefinable sounds.

Of course, the performer was famous, Atau Tanaka, a virtuoso of computer music specialising in performance using sensors on his body. Later in the conference he presented a paper exploring the affordances[6] of *iPhones* as musical instruments (Tanaka, 2010).

Tanaka's performance was based on an *iPhone* app called *RjDj* (Reality Jockey Ltd, 2008) that allowed special "patches" constructed in the *Pure Data* language on a computer to be run on the *iPhone*. He had been able to draw material from his previous works written either in *Pure Data*, or a related language, *Max/MSP*, and port them to *RjDj*.

Tanaka and others at the conference saw the *iPhone* and *iPad* as potential instruments at the focus of a performer's and audience's attentions. In contrast, my vision for these devices was to be unobtrusive computers that could perform similar musical functions as in my previous performances. Perhaps they would not be *invisible* to the audience, but at least scaled back to the same attention level as, say, a music stand or a table to hold mallets.

This inspirational experience allowed me to form a clear idea of how I might use mobile computer music devices in my percussion performances. As this thesis will describe, over the following eighteen months I explored not just one, but a variety of musical applications for mobile devices in my solo setup and in my ensemble. The resulting research project investigated not only one musical work, but the creative process enabled with these devices, their musical affordances, and their effect on performance practice in different contexts.

1.3 Researching Mobile Computer Music and Percussion

My investigation into mobile computer music systems began in an undisciplined way while working with *Ensemble Evolution* in Sweden. My rough goal was to experiment with mobile computer music devices using *iPhones*

[6]The term "affordances" is used frequently in the field of "Human Computer Interaction" or HCI and in the design of computer based musical instruments although it was a term first used in psychology (Gibson, 1977, 1979). Donald Norman defines affordances in his book on the psychology of design, *The Design of Everyday Things*, as the "properties of a thing that determine just how the thing could possibly used" (Norman, 1990, p.9). As he explains, a "chair affords ('is for') support and, therefore affords sitting."

and *iPads* with various software tools and to record and analyse the experience of incorporating them into my solo and ensemble percussion performances. Throughout 2011 and early 2012, this pursuit became formalised into the research project described below.

1.3.1 Artistic Outcomes

The artistic outcomes of this project are a portfolio of solo and ensemble compositions for percussion and mobile computer along with the associated devices and software developed for these works. Documentation of these artistic outcomes is in the form of audio and video recordings from rehearsal studio performances and concerts (see appendix B) as well as the descriptions contained in this thesis.

The artistic projects will stimulate investigation into how mobile computer music devices can work for percussionists and as complements to acoustic percussion instruments. The aspects of this investigation will be specified in the research questions below, but in general can be broken down into the following directions.

The size and simplicity of mobile devices makes them attractive as replacements for laptop computers. It was important to choose devices and peripheral audio hardware that work simply, not just by themselves, but in combination with the percussion instruments. They needed to be convenient to use in rehearsals and performances.

Sharing computer music with *Ensemble Evolution* was a key motivation for this research. The artistic outcomes include collaborations with this group where computer music applications are designed to be accessible for non-programmers. Section 4.3 will describe the discoveries made about the relationship between composer/programmer and performers in these collaborations. Finding a creative process that could accommodate rehearsals and programming was crucial.

Mobile devices feature not only small size and weight, but touch screens and other interesting interfaces such as accelerometers and built-in microphones. Part of the artistic exploration was to create ways to use these affordances that made sense to percussionists and were useful in performance. Different compositional approaches were required to accommodate these new discoveries in performance practice.

The artistic outcomes were investigated experimentally and formed three projects:

1. Creating and performing with a mobile computer music system for vibraphone to bring computer elements to *Nordlig Vinter*, a suite of

solo and duo works for vibraphone, marimba and *iOS* devices.

2. Introducing mobile computer music to *Ensemble Evolution* with *3p3p* an experimental work for percussion and three *iPhones*.

3. A tested collaborative process to develop a new work for percussion and mobile computer with *Ensemble Evolution* resulting in *Snow Music*.

Chronologically, *3p3p* was the first project completed for this research having been performed in March, 2011. The development of *Nordlig Vinter* occurred next, in September and October, 2011. Finally, the *Snow Music* project was undertaken from January to March, 2012.

In *Nordlig Vinter*, the mobile computer music system works closely together with the vibraphone as one hybrid instrument. The suite includes solo and duo improvisations and composed works for vibraphone, marimba and *iOS* devices. The live performances recorded in section 3.3 included experimentation with other *iOS* devices and substituting the marimba for a drum set. Recording and composition of works from *Nordlig Vinter* is ongoing and "in-progress" recordings are included with this document.

The two projects with *Ensemble Evolution*, *3p3p* and *Snow Music*, concern sharing computer music tools with the two non-programmer percussionists in this group. For this reason they are discussed together in chapter 4 even though they are chronologically separated by the development of *Nordlig Vinter*. *3p3p* was my first experiment using *iPhones* with *Ensemble Evolution*. In this semi-improvised work each of the three players performs with an *iPhone* as well as a percussion setup. *Snow Music* is a completely improvised work developed collaboratively with *Ensemble Evolution*. Each player uses a keyboard percussion instrument as well as an *iPhone* or *iPad* that can be played with percussion-like techniques to create "snow" sounds and computer generated backing tracks.

1.3.2 Research Questions

1. *Heaviness.* Can computer music setups be made more simple, elegant and convenient using mobile devices?

2. *Shareability.* How can mobile computer music instruments be made accessible to a non-programmer percussion ensemble, and what creative processes can be used to explore them?

3. *Playability.* How can the affordances of mobile music devices be used to create playable instruments for percussionists?

4. *Performance practice.* What new performance practices are enabled or demanded when complementing acoustic percussion instruments with mobile music devices?

This project also investigates exploratory topics. A number of technologies for developing mobile computer music devices will be trialled in the project. A range of artistic projects will be included in order to gain some insight into different rehearsal, development and performance scenarios.

1.3.3 Research Method

The research questions of this project will be addressed qualitatively through ethnographic[7] analysis of the process of developing, rehearsing and performing the artistic outcomes. These processes have been documented through written notes, audio and especially video recordings. The analysis of the most complicated of this data, the video records of rehearsals and performances, will be made through a process of coding, following techniques for analysing ethnographic data described in Krüger (2008). In this process key-concepts are chosen and assigned to events occurring in the video. Events can then be grouped by key-concept to connect the various meetings and performances. The process for coding verbal information is well understood, conversations can be transcribed and then coded easily in this form. Performances will be coded following Östersjö's (2008) method of working directly from the video. A full description of this technique is given in section 4.2.

The method of documentation was different for the vibraphone computer music project than for the projects with *Ensemble Evolution*. In the former case, documentation consists of audio recordings and images from various stages of development and performance, as well as a process diary. In the latter case, the collaborative process of creating, rehearsing and performing with *Ensemble Evolution* was documented using video recordings. It is hoped that analysis of this process will yield information about the second research question in particular, the "shareability" of mobile computer music devices.

[7]Ethnography is a qualitative research method for studying cultural phenomena. The ethnographic researcher conducts fieldwork to collect notes, audio and video recordings, and images relating to the phenomena, an active and subjective method. "The open-ended nature of the ethnographic approach is particularly suitable for active discovery and exploration" (Krüger, 2008). The analysis of the data can be an iterative process with multiple phases of field work and analysis to refine the research questions. Conclusions are drawn inductively from the data gathered.

Even though these projects address similar aspects of the research question, the different scenarios justify different methods of documentation. The case of the computer music system for vibraphone mainly concerns my perspective and experience with computer music devices which can be recorded in a process diary. However, the projects with *Ensemble Evolution* involve how these devices fit into an interaction with other musicians and so video documentation was necessary to capture the details of group discussions and performances.

The artistic outcomes were pursued experimentally with the choice of hardware and software elements informed by current trends in computer music research. An overview of research into mobile music devices is the topic of chapter 2, with attention also given to the development of new interfaces for musical expression on other types of computers. An overview of characterisations of collaboration is given in section 1.4 to help understand the musical collaborations in this research.

Documentation and analysis of developing and performing with the vibraphone computer music system is the topic of chapter 3. The two artistic projects with *Ensemble Evolution* are discussed in chapter 4. Finally, in chapter 5, these two directions are examined together to address the research questions and the motivations of this project.

1.3.4 Privacy and Documentation

Although the process of creating and performing the two artistic projects has been documented extensively through video and audio recordings and my process diary, not all of these elements are included with this document. Ensemble rehearsals and personal notes are not public and in order to preserve a sense of freedom and safety in the artistic process only excerpts from these events will be included to support the arguments made in this thesis.

The other members of *Ensemble Evolution*, Maria and Jacob, and other musicians involved in this project participated willingly and the transcripts of our discussions, recordings of our rehearsals and their real names that are included in this research are presented with their permission. As much as possible of the playing during rehearsals is included in the documentation of artistic outcomes. Although this limitation restricts the reader's access to parts of the research data, it is intended to uphold the quality of the creative process under analysis and thus ensure the quality of the research.

1.4 Collaborative Practices in Contemporary Music

It is significant to this research that the computer music systems under examination have been used in collaborative artistic practices. In order to assess the "shareability" of these systems, it is useful to understand the collaboration that is taking place. Paul Roe provides an overview of patterns of collaborations in his examination of the relationship between composer and performer (Roe, 2007, §1.4). These classifications concern the interaction of artists in general and the particular interaction between composers and performers. Two of the characterisations Roe describes, the first due to Vera John-Steiner (2000) and the second due to Hayden and Windsor (2007), are relevant to the artistic projects under consideration in this research.

1.4.1 Patterns of Artistic Collaboration

John-Steiner's characterisation divides artistic collaboration into four categories according to the extent to which the multiple artists' practices are entwined.

Distributed collaboration.

Artists share ideas through conversations, writings and published works either in informal contexts or through conferences, festivals or other communities.

Complementary collaboration.

Artists with different specialisations join forces to create collaborative work while remaining responsible for their own discipline. This mode of collaboration is defined by "a clear division of labour based on expertise" (Roe, 2007, p27), and an example might be a musician working with a dancer to create a joint work.

Family collaboration.

This mode of collaboration extends "complementary collaboration" with the kind of flexibility, intensity and interdependence that come with developed relationships between the artists. In this mode, "roles are flexible and may change over time. Levels of independence, dependence and interdependence shift and develop depending on skill levels and experience" (Roe, 2007, p27). Roe notes that "close socialisation is a key dynamic".

Integrative collaboration.

Artists have integrated their practice with each other over a long period of time to pursue a shared vision. "These partnerships are the most intensely productive, with innovative and new forms often resulting from the interactions" (Roe, 2007, p27).

1.4.2 Collaboration Between Composer and Performer

This characterisation of collaboration, due to Hayden and Windsor (2007) based on the work of Argyris and Schön (1974), is focussed on the relationship between a composer and performer in creating musical works. The different modes are defined by the level of compositional input afforded to the performers in the group.

Directive.

The "traditional" relationship between composer and performer where the composer directs the performance through a score. Although collaboration exists in this arrangement, it is "limited to pragmatic issues in realization" (Roe, 2007, p28) rather than influencing the composition of the work.

Interactive.

Although a hierarchy exists with the composer as the author of the musical work, creating the work involves a direct negotiation with the performers. As a result, the composition process becomes more "interactive, discursive and reflective" (Roe, 2007, p28). The score for the work might provide for improvisation on the part of the performers outside of the written notes.

Collaborative.

The process of composition is completely collaborative with no hierarchy of roles. The structure and content of the composition is decided through group decision making and live improvisation.

1.4.3 Collaboration in this Research

Applying these patterns to my own work, it is clear that the collaborative performances with my mobile computer music system for vibraphone can be classified as "complementary collaborations". The mobile computer music system was intended to become a part of my "instrument" that I brought to

the duo performances described in section 3.3 while the other player brought their own instrument and expertise. The composer/performer relationship for these performances tended towards "interactive". The performance was made up of my duo compositions, but these were created in negotiation with the other player and include some improvisational elements. The vibraphone computer music system also became part of "collaborative" performances such as free improvisations with no notated or pre-agreed music of any kind.

My work with Ensemble Evolution, set down in chapter 4, is more reflective of a "family collaboration". This group was designed for the intensive development of each player's performance, composition, improvisation, and management skills in a relatively isolated environment. At the time of the field research conducted for this thesis, the members had worked on a large number of projects and developed close friendships. The flexibility of roles that characterises this mode of collaboration is reflected in the *Snow Music* project described in sections 4.2, 4.3, and 4.4. Although I provided the impetus for the project and developed the computer music elements, the input of the other players had a significant impact on the direction of the project, the computer elements and the resulting performances. In this way the musical relationship between the performers was "collaborative", with no member of the group staying in a composer-like role.

2 An Overview of Research into Mobile Music Devices

The rapid pace of development of powerful computers has resulted in much progress in developing computer based musical instruments. It is easy to see that as new technologies for computing, sensing and controlling music become more accessible and inexpensive, there are bursts of activity directing them towards artistic purposes. The arrival of much more powerful mobile computers, led most recently by *Apple*'s *iPhone* and *iPad* devices, is no exception.

Although mobile computer music devices have had much development over the last few years, much more research has been carried out into the use of laptop or traditional computers in musical performance than with these mobile devices. Of particular interest is investigation into new interfaces for musical expression, that is, the hardware or software systems for controlling or interacting with computer music processes.

2.1 Research into the Development of New User Interfaces in Electronic Music

It is possible to divide contemporary computer music into several directions, following Newton Armstrong (Armstrong, 2006). The first direction is "laptop music", where performers use laptop computers, more-or-less unmodified, as instruments. While the performer may be almost motionless during a performance, a great deal of activity can happen within the computer, controlled through the usual interfaces (Keyboard, Mouse, Display). Much research has gone into the value of this performance practice and the design of software user-interfaces for laptop musicians of which Collins,

McLean, Rohrhuber and Ward's work on "Live Coding" (Collins et al., 2003) is just one example.

A second direction for computer music almost completely eschews the typical computer interface. Practitioners extend computing devices, experimenting with new technologies for sensing the performer's gestures. An historical example of this practice is *The Hands* (Waisvisz, 1985), developed by Michel Waisvisz, which are a set of handheld controllers with multitudes of sensors and buttons. These controllers were designed, at first, to control hardware synthesisers, later versions controlled computer based synths.

A stream of my own previous work was in the latter direction. My cross-artform group, *Last Man to Die* produced a series of theatre based performance works (Martin et al., 2010a,b) where props, costumes and the set were integrated with sensors to control musical and visual processes. Synchronised over a network, visual, musical and haptic feedback (via small vibrating motors) integrated the performers with the theatre, the audience and each other.

Finally, a third direction is to use computers to augment existing acoustic instruments. This augmentation could be in the form of signal processing (effects) or computer sounds produced when sensors detect the performer's actions playing their instrument. In this very well explored direction, the performer's gestures may be detected by electronic sensors attached to the instrument or performer, as in Bongers' *Meta-Trumpet* (Bongers, 2007), by some kind of visual tracking as in my work *Strike on Stage* (Martin & Lai, 2011), or the sound of the instrument is captured by pickups or microphones as in *Patch for Guitar* (Puckette, 2007). Often a combination of technologies is used and the computer sound produced from a variety of processing and synthesis techniques.

My work in this direction, *Strike on Stage*, was the result of my collaboration with fellow percussionist and computer musician, Chi-Hsia Lai. In this piece, a large portable projection screen and computer vision system was used to detect "percussive" gestures by two performers seated in front of the screen with acoustic percussion instruments. Using this data, the sound and visual impact of the percussion performance was augmented with computer based sound and projected visuals.

This direction also represents the form of computer/electronic music with the longest tradition. A common thread of performance practice that connects Stockhausen's early works for percussion and electronics such as *Kontakte* (1960) or *Mikrophonie I* (1964) with my current work *Nordlig Vinter*, described in section 3.3. In this kind of music, the computer or electronics part can assume a number of performative roles within the composition: a backing soundscape, a traditional musical accompaniment, a

reactive or augmentative relationship with the acoustic instrument, or a completely controlled role where the computer sounds are directly activated by the performer. These roles and their relationships with percussion performance practice are explored in my previous research (Martin, 2009), influenced by John Croft's work on "liveness" in music for instrument and electronic sounds (Croft, 2007).

2.2 Why is Mobile Interesting?

> I've come to believe that there is something intrinsic to the computer that necessarily and inevitably brings about a disconnect. (Armstrong, 2006)

Using mobile devices as replacements for laptop computers in the research listed above is certainly desirable for many researchers and computer music performers. It is valid to ask why this might be the case when modern laptops provide vast computational powers, very flexible software configurations and are easily extended with experimental interfaces to sense all kinds of interactions. In contrast, mobile devices have much lesser computational power, have (historically) more limited software capabilities and cannot easily be extended with experimental interfaces.

One reason is the elegance of modern mobile devices compared to laptop based computer music setups. Authors developing mobile music are quick to mention that modern mobile phones come equipped with a variety of sensors, such as accelerometers and multi-touch screens, that would have to be added to laptops (Tanaka, 2010; Wang et al., 2008). They also have ample computational power for most computer music tasks. So, rather than an "instrument" constructed from a computer wired to external interfaces, mobile music devices can achieve similar kinds of interactions between performer and computer using only one hand-held device.

One of the few published criticisms of laptop and desktop computer technologies for developing new musical interfaces is in Berdahl and Ju's paper on their mobile computer music system (Berdahl & Ju, 2011). These researchers at Stanford University's CCRMA are concerned for the "very short lives" of new computer musical instruments that result in a lack of performance expertise, quality composition or refinement in this field. As we have described, new computer musical devices tend to consist of a combination of custom electronics, audio equipment and laptop computers. Berdahl and Ju see the laptop computer as the "weak link":

> Because computers are expensive, people seldom devote separate computers to their NIME[1] designs; instead they use the same machine that they are writing emails and theses on as the critical engine of their new musical instruments. These instruments thus suffer collateral damage every time we upgrade our operating systems, or install a new version of Java, or switch to new hardware. (Berdahl & Ju, 2011, p. 174)

The mobile computer music system *Satellite CCRMA* that Berdahl and Ju have developed, addresses this issue by combining all the elements of typical computer music devices into a single inexpensive system. These systems can be dedicated to single projects to avoid fragmentation or loss of functionality due to upgrades.

Moreover, while computer and digital technologies seem to have so much to offer musicians and composers in terms of sonic variety, the result of computer performance practice can often be disappointing compared to acoustic instrumental practice. Aden Evens suggests that acoustic instruments, through their very physicality and limited timbral variety, allow creativity and expression (Evens, 2005). In fact, Evens argues, musical creativity and the generation of new ideas, sounds and musical directions is rooted in the battle between performer and "resistance" from an instrument that will "push back, make itself felt, get in the way, provoke or problematise" (Evens, 2005, chap. 4). Evens argues that computer based instruments will have to adopt some aspects of this resistance to help transform creative desire into musical output:

> Taking a cue from the musical instrument, it is clear that what the computer needs is a resistance, a problematic resistance that, when pressed by a creative desire, turns that desire into expression, generating the new. This formula, not so easily said, is nevertheless much more easily said than done. For though the computer certainly resists the desire of the user, it does so with a rigidity, a fixity that tends only to demand conformity rather than engender creativity. In order to do things with a computer, one must use it according to its prescribed options, and no other usage is the least bit productive. The computer's resistance is predefined by the reigning architecture. It is not a pliable material resistance, with a leading edge of indeterminacy, but a fixed logical resistance, in which every response is calcula-

[1] New Interface for Musical Expression

> ble, repeatable, and determined in advance. (Evens, 2005, chap. 4)

It is possible that mobile devices can "resist" the musical performer more than laptop computers. Mobile devices lend themselves to much more focussed user interfaces than the "windows" model on laptops. Their lack of traditional interfaces (keyboard and mouse) promote total reliance on other sensors for musical interactions. Finally, their handheld size and simple connectivity options can simplify stage setups and could generate more opportunities to hold performances.

2.3 Available Hardware

2.3.1 *Apple* Devices

The focus of my research into mobile computer music devices, and many others over the last four years, has been *Apple*'s *iPhone* and *iPad*. Neither of these devices were the first mobile computers of their size nor were they the first to be used by music researchers. Notably, *Nokia*'s *N95* was the first model used in Stanford's *Mobile Phone Orchestra* (Wang et al., 2008). However, the *iPhone* and *iPad* did offer new user interface paradigms by relying on large multi-touch screens for the majority of interactions. Both devices also feature a variety of sensors: 3-axis accelerometer, digital compass, GPS, ambient light sensor and microphone. The promise of combining interesting interfaces and sensors, signal processing and sound output in these mobile devices was interesting to computer musicians.

Apart from their hardware, *Apple*'s *iOS* devices[2] (now including various models of *iPhone*, *iPod Touch* and *iPad*) feature an extremely well designed software development process. Importantly, all of these devices use *Apple*'s mature and stable Core Audio library for playing and processing sound, which drew computer music researchers away from other mobile technologies[3]. A result of these software features was that it was relatively easy to port mature computer music tools from the desktop operating system *Mac OS X* to *iOS*; a number of these tools are discussed in later sections.

The *iPhone*'s popularity resulted in another phenomenon - the "app store". Computer musicians responded by publishing instruments and sonic

[2] "*iOS*" is the name of the operating system that runs on the *iPhone*, *iPod Touch* and *iPad* and these devices can be collectively called *iOS* devices.

[3] Anecdotal evidence suggests that developing and distributing software for *Nokia N95*s was "like pulling teeth".

toys through this new channel. *Smule*, founded by Stanford researchers, focusses on apps that combine traditional musical experiences with game-like interaction, such as *Magic Fiddle* (Wang et al., 2011) which was aimed to reach a broad audience.

Other researchers publish more esoteric software, experimenting with computer instruments and interfaces. Nick Collins's app, *Con:cat* explores "concatenative synthesis", where sounds recorded through the *iPhone*'s microphone are synthesised using the best-fitting clips of other recorded sounds.

Another app, *Crackle* (Reus, 2011) by Jonathan Reus, is inspired by a noisy synthesiser toy, the *CrackleBox*. Reus focusses on developing a simple touch interface with a deep connection to synthesis algorithms to create an expressive yet simple instrument. This project also connects the history of electronic music with current practice. The *CrackleBox* was developed and produced by Michel Waisvisz at STEIM in the 1970s as part of a range of "crackle" instruments (Waisvisz, 2004). Perhaps mobile devices are the first computers that can achieve a similar level of intuitive exploration and expression in the same compact and wireless form as the *CrackleBox*. From a percussionist's standpoint, apps like Reus' *Crackle* seem to have potential as one element in part of a larger setup. After all, percussionists are trained to use multiple simple instruments in one setup to create complex music.

Apps that provide effects or other enhancements to an existing instrument might also be particularly useful to percussionists. *IK Multimedia*'s *Amplitube* is just one of many commercial apps focussed on providing guitar effects while Dan Overholt's *Overtone Fiddle* integrates an *iPod Touch* into an electric violin for signal processing and augmenting the instrument's sound.

2.3.2 Mobile Computer Development Systems

Despite the explosion of mobile music research based on the *iOS* platforms, there were developments prior to these devices and there are still good reasons to explore other technologies today.

Greg Schiemer's composition *Pocket Gamelan* (Schiemer & Havryliv, 2007) was created for an ensemble of *Nokia 6230* mobile phones which could run programs written in the mobile version of the *Java* programming language (*j2me*). Although Schiemer and his colleagues made progress in computer music programming for this language (Schiemer & Havryliv, 2005), the project eventually moved towards using other mobile technologies (Schiemer & Cheng, 2009).

Martin Kaltenbrunner contributed to *PdPod*, a distribution of *Pure Data* for a now discontinued version of *Apple*'s *iPod* which was reverse engineered to run a Linux based operating system (Kaltenbrunner, 2005). Only one application of this software is known, a hurdy-gurdy style noise instrument called *Slåttberg* created by Espen Sommer Eide (Eide, 2008; Kirn, 2008). Another port of *Pure Data* was created by Günter Geiger, who researched the possibilities afforded by Compaq's *iPaq* devices in 2003 (Geiger, 2003, 2006).

The above computer instruments have used consumer electronic products, repurposed or modified for use in performance. Another option is to use development or prototyping platforms as mobile computer music devices. The *BeagleBoard* (beagleboard.org, 2008) is such a platform. While an *iPad* contains computer hardware, a battery, screen and housing, and pre-loaded software, the *BeagleBoard* consists of one circuit board with a processor, memory, and connectors to add additional components but no screen, battery, or case. The idea is that developers can create prototypes of their own mobile computers using the *BeagleBoard* as a "brain".

Satellite CCRMA (Berdahl & Ju, 2011) is a software platform that allows computer music devices to be created for *BeagleBoard* using *Pure Data*, or other computer music software. The idea behind *Satellite CCRMA* is that a *BeagleBoard* might be integrated into experimental computer instruments and interfaces rather than tethering the instrument to a laptop. A similar project, *Audiopint* (Merrill et al., 2007) was aimed at creating a rugged, portable computer running an optimised *Linux* operating system and *Pure Data* that would be suitable for using on stage or in installations.

There are other possibilities for mobile music devices based on development platforms. The *Codec Shield* (Open Music Labs, 2012) couples with the *Arduino*, a popular development platform, to allow high quality audio processing. The *Raspberry Pi* (Upton, 2012) is an extremely inexpensive single-board computer designed to allow children and students to experiment with computer programming. Either of these devices could be the basis for creative music making, but as they have become available only very recently (early 2012) only time will tell what potential they have.

2.4 Development Frameworks for *iOS*

My research has been focussed on using *Apple*'s *iOS* devices as the basis for developing computer music devices. Even within this one family of hardware, there is a range of different software platforms for creating computer musical instruments and compositions. As the case studies in chapters 3

and 4 describe, throughout the process of my research I experimented with a number of these platforms and settled on a combined approach to suit different situations. This section surveys the main computer music software platforms available for *iOS* at the time of this thesis, including those that were used to meet the artistic outcomes.

2.4.1 *RjDj*

RjDj (Reality Jockey Ltd, 2008) is a consumer oriented app for *iOS* devices for creating reactive musical environments. Users download and play "scenes" which perform algorithmic compositions and process sounds entering their device's microphone, while sound artists can create scenes and distribute them through *RjDj*'s website.

In fact *RjDj* contains an implementation of *Pure Data* and the "scenes" are encapsulated *Pure Data* programs. The *RjDj* app captures information from the *iOS* devices' sensors and audio input and allows a *Pure Data* program to access this information in a simplified way.

While the developers of *RjDj* envisioned consumers using *RjDj* to create the "soundtrack to your life" (Reality Jockey Ltd, 2008), computer musicians saw its potential in performance. In particular, Atau Tanaka and Adam Parkinson have created four-hand *iPhone* performances using this technology (Tanaka, 2010).

One of *RjDj*'s strongest advantages for computer music development is that scenes can be developed and distributed without developing an entire app for the *iPhone*. Creating an *RjDj* scene involves composing the scene in *Pure Data* using the correct objects for audio and data input and output inside *RjDj*, and then transferring the scene over an internet connection using a program supplied by *RjDj*'s developers.

Creating a scene in this way is much simpler to accomplish than developing an entire native app for *iOS*, which involves some understanding of *objective-C*, a much more complex language than *Pure Data*, and entering into a developer agreement with *Apple* which has a yearly subscription fee.

For this reason, *RjDj* is an excellent starting point for experimenting with mobile music devices. Some important downsides to creating *RjDj* scenes for performance is that the *RjDj* app contains extra features, access to a "scene" shop and a social network, which can have a negative impact on the performance of the scene. *RjDj* scene development is not well documented and this situation will probably not improve as the developers have moved their focus to other projects.

2.4.2 *MoMu*

MoMu, for "Mobile Music Toolkit" (Bryan et al., 2010) is a set of software tools for *iOS* devices that are designed to enable faster and easier development of mobile computer music applications. The toolkit provides a simpler programming interface to audio input and output, the devices' sensors and multitouch screen. Additionally, the toolkit includes an *iOS* port of the *Synthesis ToolKit* (*STK*), an open sound control library based on *OSCPack* and a set of graphics tools for creating rich user interfaces.

With these extra programming tools provided by *MoMu*, it is much easier to develop a mobile computer music applications on *iOS*. The toolkit was used in Stanford CCRMA's Mobile Music class to rapidly develop a suite of compositions for their *Mobile Phone Orchestra* (*MoPho*). As an example, *MoMu* provides a programming object, *MoAudio*, that interfaces with the audio libraries in *iOS*. *MoAudio* uses the "best practice" method of accessing audio input and output on *iOS* devices and encapsulates over 700 lines of *iOS* code in just 2 lines.

Developing an application using *MoMu* involves programming in the *objective-C* language, as well as *C/C++*, a de-facto standard and older relative of *objective-C*. My main experience with *MoMu* was in attending a programming workshop at the New Interfaces for Musical Expression conference in 2010. Overall, the workshop convinced me that the toolkit was useful and worth investigating. However, I couldn't see an easy path for using the toolkit for composing a musical interaction or piece. The toolkit includes *STK*, a well known *C++* library for digital signal processing but not a language for musical composition.

On the other hand, *MoMu* is a modular toolkit and a selection of its elements (e.g. the sensor and multitouch interfaces) could easily be combined with other software tools to help create an interactive computer instrument.

2.4.3 *iSuperCollider*

iSuperCollider is an experimental port of the *SuperCollider* (McCartney, 2002) language and synthesis system to *iOS*. It allows SuperCollider scripts to be performed and created on *iOS* devices. Although it is not distributed as a finished product, the source code is freely available and a determined developer can compile and use it on their own devices.

Dan Overholt's Overtone Violin (Overholt, 2011) is the only project I know of that uses *iSuperCollider* in performance. As mentioned earlier this electric violin includes an *iPod Touch* built into the body. *iSuperCollider*

is then used to process the sound from the instrument's pickup which is dispersed from a small speaker also built into the violin.

2.4.4 *libpd*

libpd (Brinkmann et al., 2011) is a general project to port *Pure Data* to a number of platforms. Rather than creating a "*Pure Data*" app for *iOS* or other mobile devices, *libpd* is an effort to separate the audio synthesis parts of *Pure Data* from its graphical programming interface. The idea is to allow *Pure Data* to be used as a synthesis library for other applications. For example, a computer game might use various graphics libraries to display the visual elements and have a soundtrack composed in *Pure Data* and embedded in the application using *libpd*.

Among several other important platforms, *libpd* has a distribution for *iOS*. The process of developing a piece using *libpd* is somewhat like the process for *RjDj*. The sounds are created in a special *Pure Data* program which is embedded in the application. However the developer must also create other parts of the *iOS* application before it will work. In most cases, some kind of interface using the multi-touch screen, or the *iOS* devices' sensors will be necessary for a useful application. The developer will need to create these parts of the application in *objective-C* or using some other wrapper library (such as *MoMu*).

The main advantage of developing a native app in *libpd* rather than developing an *RjDj* scene is that the native app has significantly more potential to become a polished product. There are also performance advantages, *RjDj* is limited to a sample rate of 22.05khz while *libpd* can run at 44.1khz, the standard "CD Quality" sample rate. Since an app using *libpd* has full access to the sensors and multitouch interface, it is possible to create a much deeper interface for performance than might be possible with *RjDj*. Once a developer has overcome the hurdle of *objective-C* programming, it is also much easier to test a native app than an *RjDj* Scene which could improve the quality of the interactive experience and the music.

2.4.5 Other Systems

It is worth noting that *openFrameworks* (Lieberman et al., 2008), "an open source C++ toolkit for creative coding" can also be embedded in *iOS* projects. Somewhat like *MoMu*, *openFrameworks* provides easier access to sensors, multitouch and audio and graphics libraries while still producing a native application. Incidentally, *libpd* is also available for *openFrameworks*, so one could embed a *Pure Data* composition inside an *openFrameworks*

interactive application inside an *iOS* app. Although this sounds unwise, it could be a reasonably accessible development workflow although it is beyond the scope of this project to test it.

3 A Mobile Computer Music System for Vibraphone

My specifications for a vibraphone computer music system were defined by my experiences of travelling around the world presenting concerts and working with other musicians and artists. I often want to perform using computer music tools as well as percussion, but am usually limited by the size and weight of equipment that I can bring with me.

My interest in performing music on vibraphone and computer began in 2008 with a number of performances documented as part of my masters' studies at the Australian National University (Martin, 2009). These performances, *Duet for Vibraphone and Computer*, used microphones and various reactive computer music elements on a laptop to allow the computer part to react to my playing on vibraphone. The amount of equipment used for these concerts may not have been terribly heavy (in addition to the vibraphone, a laptop, audio interface, microphone, cable and microphone stand), but recent developments in mobile computer inspired me to minimise this equipment and create a system that might be able to fit inside my stick bag or backpack and integrate more elegantly with the vibraphone.

Apart from saving space and weight when travelling, I hoped that a more simple and elegant system might be valuable in collaborations. If the cost and complexity of the system was low enough I might be able to help others put together new versions or even run workshops or classes in creating portable computer music systems.

Since I generally borrow a vibraphone to play when travelling, I could not include special modifications to the vibraphone as part of my setup. This rules out contact microphones which have to be glued onto the bars, and any attachments that can't be achieved with Blu-tack or Velcro. I was also conscious of the challenges of using electronic music equipment in a classical setting. Percussion concerts often involve moving large instruments

between pieces. For this reason it was better to have fewer cables connecting my computer system to power and the loudspeakers on the stage. This would also reduce the amount of time needed for sound checks when set up and rehearsal time was limited.

To share this system with others I wanted it to be inexpensive and even possible for others to construct and use in a workshop or class. In this respect, I was inspired by Nicolas Collins' work (Collins, 2009) in using and teaching handmade electronics for music and art.

3.1 The Specifications

The specifications for my system were divided between reducing the size and weight and creating a system that could be shared with and built by other musicians.

3.1.1 Size and Weight

- *Small.* The whole system should be able to sit on the end rail of a vibraphone or marimba. Velcro or Blu-Tack attachments could be made for safety.

- *Light.* The whole system should be less than 500g for one player. It needs to have minimal impact on a carry-on bag for travel (total limit 7–10kg).

- *Programmable.* It should be able to run custom programs allowing complete control over processing the input signal playing composition algorithms.

- *Battery powered.* The whole system should be able to run on batteries to eliminate the need for running extra power outlets on a stage.

- *Easy to set up.* The system should be quick to install on a borrowed instrument in a short amount of time before a concert.

3.1.2 Buildable and Teachable

- *Inexpensive.* It shouldn't be too expensive to set up more computer music systems for an ensemble or class. Apart from the computer and the loudspeaker system, the cost for the parts of the system should be under 700SEK/A$100.

- *Buildable.* It should be possible for non-experts to put together this system in a workshop situation.

- The programming aspects of the computer system should be accessible for others who are interested. There should be enough interesting creative options that do not require programming for those who aren't programmers!

3.2 A Prototype Computer Music System for Vibraphone

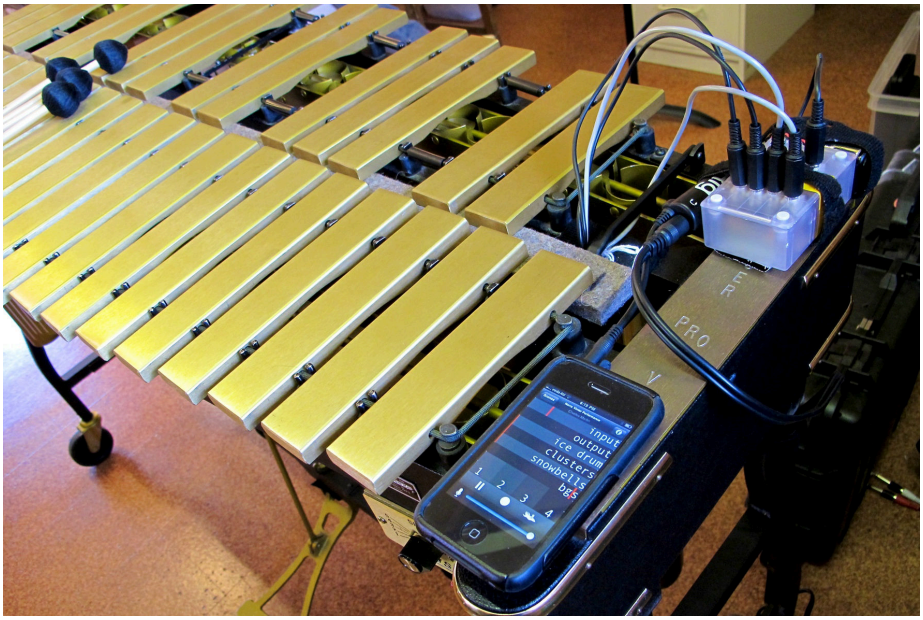

Figure 3.1: The prototype vibraphone/*iPhone* system installed on the instrument.

A prototype of my computer music system for vibraphone was completed in September 2011 in Canberra, Australia. The system included an array of microphones for processing the sound of the vibraphone and a special *RjDj* scene on the *iPhone* with sound output as a stereo pair. The system was completely battery powered and small enough to site on the end rail of the vibraphone.

The system contents:

1. Four electret microphones attached to the vibraphone's damper pedal with blu-tack (shown in detail in figure 3.2).
2. A battery powered preamp and power supply, inspired by Collins' schematics (Collins, 2009), for the microphones that mixes them down to a mono signal. (parts cost ≈ 210SEK/A$30, displayed "in-progress" in figure 3.3).
3. An *IK Multimedia iRig* dongle[1] which separates the microphone input from the headphone outputs in the *iPhone*'s mini jack connector (250SEK/A$35).
4. An *iPhone* running *RjDj*.
5. A custom *RjDj* scene containing computer music elements for my suite of compositions, *Nordlig Vinter* (programmed in *Pd*).
6. A stereo DI box[2] to allow the sound output from the *iPhone* to be easily connected to a mixing desk (250SEK/A$35).

This system met most of the specifications for the vibraphone computer music system and the total cost, apart from the *iPhone*, was around 700SEK/A$100. The self-built microphones and preamp were helpfully low priced but also allowed the project to be designed specifically for the vibraphone. These parts could be improved with some more expertise in electronics but it would be difficult to replace them with commercially available equipment while keeping the same level of simplicity and elegance in this system.

3.3 Performances and Experiences

After this prototype was completed in September 2011, it was used in performances of *Nordlig Vinter*, a suite of compositions for *iOS* and percussion as well as in other collaborative improvisations and a classroom workshop.

3.3.1 *Nordlig Vinter*: Works for Percussion and *iOS*

Nordlig Vinter is a project that I began in April 2011 to compose duo works for vibraphone and marimba, initially to perform with my artistic supervi-

[1] `http://www.ikmultimedia.com/irig`
[2] `http://www.behringer.com/EN/Products/DI20.aspx`

Figure 3.2: The microphones attached to the bottom of the damper bar.

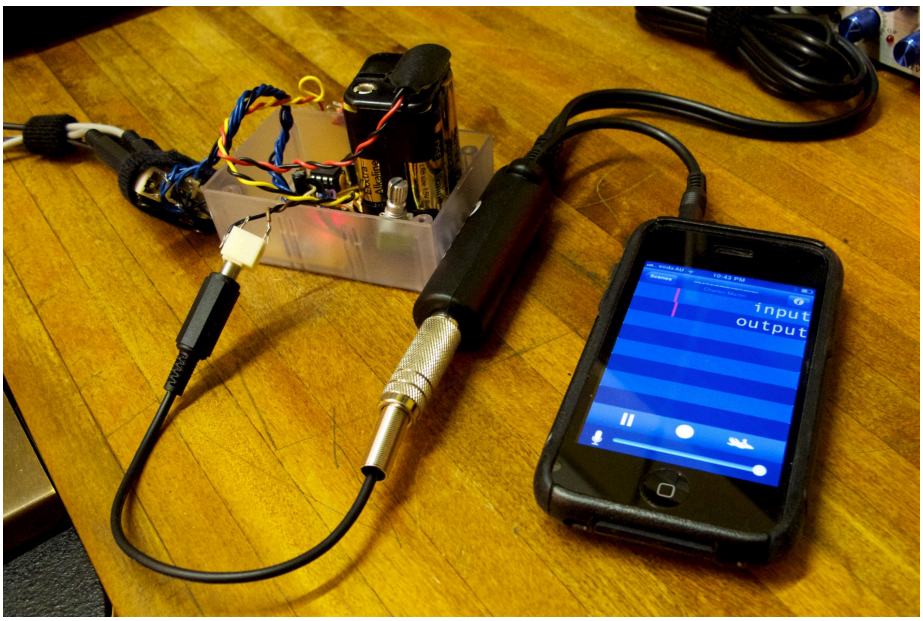

Figure 3.3: The microphone preamp and *iPhone* "in-progress".

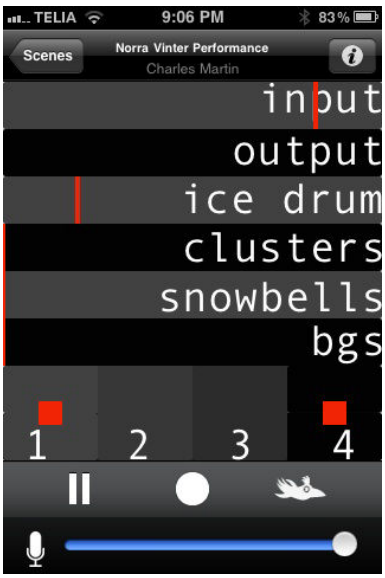

Figure 3.4: The *RjDj* interface for performing *Nordlig Vinter*. The horizontal areas with red markers give visual feedback showing the input and output levels and the current progress through each section of the composition. The numbered areas at the bottom are buttons that start and stop each section of the composition and turn effects on and off.

sor, Anders Åstrand. The cold, dark, and snowy winter in Piteå was already a source of inspiration for several of my compositions and computer music ideas and so I decided to put these together into a suite of compositions as part of the artistic outcomes for my master's studies. Musically, I wanted to put elements of the free improvised style for percussion and computer I had developed in previous works together with new approaches to improvisation and composition on vibraphone that I was pursuing in Piteå.

To achieve this goal, the suite includes composed duos for marimba and vibraphone without a computer part, as well as pieces where both players can improvise over a background composition generated by an *RjDj* scene (see figure 3.4). Two improvised pieces in the suite, *Ice Drum* and *Clusters*, are just for vibraphone and the computer music part. These two pieces also make use of the microphones in the vibraphone computer music system to apply effects to the vibraphone sound.

The computer parts for *Nordlig Vinter* are all generated by the *RjDj* scene. These parts are generative, with the *Pure Data* program at the core of the scene choosing where to play each note or sound based on an algorithm. They are also partly composed since timings for the entry of

certain layers of sound and the overall timings of the works are hard-coded into the scene. The *RjDj* scene was designed to require very little physical interaction during a performance. The scene has four buttons across the screen, the grey squares marked 1 to 4 in figure 3.4. The three compositions are started by the first three buttons. Red markers show the current position of each of the compositions which stop automatically after the markers reach the right-hand side of the screen. The fourth button toggles a reverb effect that can be applied to the vibraphone. The first two horizontal meters display the input and output volumes. These are useful to determine quickly whether the microphones on the vibraphone and the sound output from the *RjDj* scene are working.

The recording of *Nordlig Vinter* included with this thesis (see appendix B.1) is an "in-progress" view of an ongoing work. This recording is available for open access on the internet while a CD and digital publication of the work is planned for July 2012.

3.3.2 *Nordlig Vinter* at *Electrofringe*

Figure 3.5: Christina Hopgood (left) and Charles Martin performing *Nordlig Vinter, works for* iOS *and percussion* at *Electrofringe* 2011 in Newcastle, Australia. (Photo courtesy of Adam Thomas.)

Electrofringe[3] is a yearly festival that features experimental electronic arts and culture as part of a larger arts festival *This is Not Art* held each October in Newcastle, Australia. I performed *Nordlig Vinter* as a percussion duo with Christina Hopgood in a performance night that included several other artists. The vibraphone computer music system was used in improvisations that connected each piece in the program.

This performance was a practical challenge for this system and for my idea of performance. The venue was a noisy and crowded pub with a "rock and roll" style PA system and a small stage. There were a large number of performers for the evening with many different kinds of instruments and a variety of bizarre technical requirements. This situation was familiar to me from my experiences in rock bands, but was far from the traditional "classical" performance setting.

Even in a challenging environment, we were able to set up the stage for our performance in around 5 minutes and performed after a very short sound check with only enough time to make sure all the instruments were working. The only technical difficulty was that I wasn't able to use the effects in my *RjDj* scene due to feedback through the PA system's monitor speakers. It's possible that with a more substantial sound check and more careful signal routing that this problem could be eliminated.

At the same time as this concert, I publicly released a version of the *RjDj* scene for *Nordlig Vinter* with minor adjustments that oriented it as a "reactive" composition for a general audience (screenshot shown in 3.6). This scene is available as a free download through the *RjDj* app[4].

3.3.3 *drums + gadgets*

In November 2011, I travelled to Columbus, Ohio to collaborate with Noah Demland, a fellow percussionist. My visit was centred around leading a workshop in improvisation for Noah's high school music classes but we also took the opportunity to produce a small concert in a new performance and gallery space called Feverhead that was owned by one of Noah's friends.

drums + gadgets was to be an improvised concert of music for percussion and computer. Each of us contributed one of our semi-composed works which we arranged to play on vibraphone and drum set. We also created a number of improvised pieces using some of Noah's unique percussion instruments and my *iOS* based computer instruments.

[3] `http://electrofringe.net/`

[4] `http://rjdj.me/music/Charles%20Martin/Norra%20Vinter/399/`

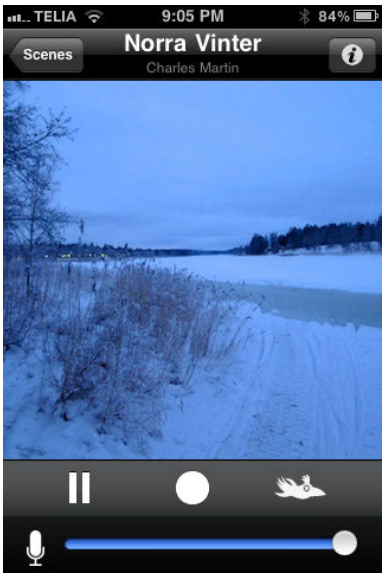

Figure 3.6: The publicly available version of *Nordlig Vinter*'s *RjDj* scene. Tapping the picture in the centre of the screen cycles through sections of the composition and effects process the sound input through the microphone.

Figure 3.7: Charles Martin and Noah Demland performing in their duo concert, *drums + gadgets* in Columbus, Ohio, November 2011.

Taking elements from my *Nordlig Vinter* suite that was performed at *Electrofringe*, Noah and I played a new interpretation of this work as an improvisation for vibraphone, drum set and *iOS* using the vibraphone computer music system and the *Nordlig Vinter RjDj* scene. Rather than a series of composed pieces with improvisations and computer based elements in between, the work became a continuous improvisation interacting with the computer parts and recalling themes from the composition.

In the other improvised pieces, Noah and I agreed that I would play mainly *iOS* based instruments and Noah would focus on percussion. As well as some synthesiser programs on *iPad* I discovered that I could use a contact microphone with the *iPhone* instead of the microphones that I had designed for the vibraphone computer music system. With this new discovery I could easily experiment with processing the sound of some of Noah's instruments using effects I had included in *RjDj* scenes. In the end, I settled on using the contact microphone with Noah's "washing machine drum"[5]. I also used the *iPhone* and *RjDj* scenes for processing the sound of a mini synthesiser I was using.

Some of these new developments were carried over into the improvisation workshop that I led for Noah's students. The students generally played guitars, keyboards and percussion in the workshops that focussed on composing and improvising ambient soundscapes, but I found that I was able to produce some stimulating background sounds for their explorations using the tools I had created in *RjDj* and the electronic instruments used in the concert.

Overall the concert and workshop allowed me to perform with many of the *iOS* computer music applications and electronic instruments I had been experimenting with. It was gratifying to experiment and develop some of these ideas as part of collaboration.

3.4 Preliminary Conclusions

It is interesting to evaluate the performance of my vibraphone computer music system in these two experiences against the research questions set down in section 1.3.2.

3.4.1 Heaviness

The vibraphone computer music system was specifically designed to minimise its physical mass and stage presence. The whole system can fit com-

[5] literally the inside of an old washing machine

Figure 3.8: The stage setup for "Drums and Gadgets" including computer instruments running on an *iPhone* and an *iPad*.

fortably in my mallet bag and can be set up on a vibraphone without any additional stands or tables. The system is completely battery powered with output suitable for direct connection to a PA system. As demonstrated at *Electrofringe*, the system can be set up in 5 minutes and can work with minimal sound check although, as always, a more careful sound check will improve the musical result.

The main time-saver seems to be the use of *RjDj* on an *iPhone* as the only computer sound source. Previous experiences with using percussion with laptops (Martin & Lai, 2011; Martin, 2009) required an array of computer music software. Complicated configurations and numerous points of failure in these systems were always a source of anxiety for me and much time was spent opening software in the correct order and double checking settings to avoid problems. Although it is possible for an *iPhone* to crash or an *RjDj* scene to work incorrectly, the process of restarting the phone and opening a scene in *RjDj* is so streamlined that it takes less time in practice and causes far less anxiety.

3.4.2 Shareability

One of the considerations for designing this system was to allow me to help others to create similar systems for vibraphone or other instruments. At the time of this research, I have only gone as far as demonstrating and explaining the system to other musicians. This idea could be further explored in the future.

It is worth noting that the public version of *Nordlig Vinter*'s *RjDj* scene has been downloaded over 7000 times since September 2011. Although this is more a demonstration of the general popularity of *iOS* devices than the particular popularity of *RjDj* or the attractiveness of my composition, it is remarkable how far the reach of this technology is. It would be almost inconceivable that a Max/MSP, SuperCollider or *Pure Data* composition distributed for these desktop computer programs could be downloaded and run by 7000 listeners on their own computer but this seems to be easily possible for mobile computers. Business or artistic opportunities aside, this definitely makes this little side project my most-heard composition.

3.4.3 Playability

The design choice to use the *iPhone* with *RjDj* as the computing environment for this project put serious constraints on the visual interface for the computer instruments that were developed. *RjDj* allows scene developers only two-thirds of the already small *iPhone* screen for displaying controls that could control the musical composition such as buttons or sliders and displaying visual feedback about the state of the composition. Furthermore, the tools for programming interactive elements and displaying information in this area are extremely limited. Overall, *RjDj* is focussed on the sonic rather than visual experience when playing back scenes. As a result, the interface for my scenes was necessarily simple, with just four buttons (see figure 3.4) for controlling each musical component of the scene and meters that show the state of the composition. In practice the *iPhone*'s screen was so small and the information so limited that I rarely thought to look at it, let alone rely on it as part of the performance.

While these limitations may require some creative thought during the development of scenes for this system, they actually increase the playability of the whole system. The developer must either use very simple graphical controls for scenes, or else abandon graphical controls altogether, relying entirely on pre-composed or generated timelines of events or using the sound of the vibraphone to influence musical processes on the *iPhone*. Both solutions allow the player to focus on playing with minimal interruption or

distraction. When composing the *Nordlig Vinter* scene for this system, I found that the limitations freed me from creating a complicated system to control or configure the course of each computer-based section of the work. I was also forced to create more polished compositions in *Pure Data*, thinking, for example, of the scene's behaviour at the end of the section when I couldn't expect myself to manually turn off a control while also playing.

3.4.4 Performance Practice

The *Nordlig Vinter RjDj* scene created for the vibraphone computer music system and used in these two performances was intended to play background sounds for improvisations and for effects processing of the vibraphone sounds.

This functionality enabled a greater variety of timbre and texture than is generally available on marimba and vibraphone. The concert at *Electrofringe* featured through-composed pieces as well as free and semi-composed improvisations motivated by the sounds produced by the *RjDj* scene. At *drums + gadgets*, the lines between these performance modes became more blurred. In that performance, I blended elements of the compositions and improvisations together into one piece, continually using background sounds and effects from the *RjDj* scene. This style of performance is perhaps closest to my previous work with computer music and percussion described in section 2.1 with the *iPhone* computer music system replacing the laptop.

When creating the *drums + gadgets* concert with Noah Demland, we discovered that this computer music system was not just useful for vibraphone. Other instruments could be processed with effects in my *RjDj* scenes, using direct inputs for electronic instruments, the vibraphone microphones or contact microphones. The simple modularity of this system enabled and encouraged this kind of experimentation with a corresponding result in creativity.

3.4.5 Limitations

The flexibility and elegance of the vibraphone computer music system in performance is offset by a more convoluted development process for the computer music instruments and compositions. To produce an *RjDj* scene, the musical elements are composed on a computer using *Pure Data*; the scene is then transferred to the *iPhone* and accessed through the *RjDj* app. It is possible for a scene to function on the computer but not on the phone due to the more limited computer resources available on the mobile device or limitations in the implementation of *Pure Data* included in *RjDj*. The

process of loading the scene onto the phone takes time and so the debugging process can be frustrating. As a result, it is necessary to develop higher quality computer music software for *RjDj* than might be required on a computer due to the time required to make alterations.

Another limitation of this system is in sound quality. Although the home-made vibraphone microphones are cheap and unique, the quality of the battery-powered preamp is only just adequate for the purpose. It is possible that, with more experience in electronics, a better solution could be produced, or a commercial solution that meets the specifications might become available. When feedback problems occurred at the *Electrofringe* concert the easiest solution was to disable the effects system altogether rendering the microphones useless. Perhaps some finer control over the microphone gain or finer controls in the software could address this problem. Although further experimentation in microphones and pickups could yield a more playable system, the current equipment is playable enough to be used in performance situations and for the continued development of works for vibraphone and mobile computer.

4 Computer Music with *Ensemble Evolution*

Much of the creative work discussed in this thesis was inspired by my work with *Ensemble Evolution* in Piteå. Our varied performance backgrounds but joint passion for percussion encouraged me to share computer music making with them. The pace of our projects and ambition to create new works and perform around the world inspired me to create more elegant instruments and more rapid creative processes. In this chapter, I will discuss two performance projects undertaken with *Ensemble Evolution* using *iOS* devices with acoustic percussion instruments. Chronologically, these projects fit around the work in chapter 3. The work discussed below, *3p3p*, was my first experiment in performing with mobile computing devices while the work *Snow Music* is the latest work discussed in this thesis. While *3p3p* is notable because it was an entirely new performance method for the group, *Snow Music* represents the most developed ideas in creating and performing with mobile computer instruments. Additionally, the creative process and performances of *Snow Music* were video recorded as part of this research product. Qualitative analysis of these events provides a deep insight into the research questions.

4.1 Early Explorations: *3p3p*

One of the main motivations of my work with mobile computer music was to allow the members of my percussion group, *Ensemble Evolution*, to perform with computer music sounds as well as percussion. I was reminded in early 2011 about *RjDj*, the *iPhone*-based interactive music player. It struck me that since each performer in *Ensemble Evolution* had an *iPhone*, we could each run *RjDj* on our phones and use the phones in performance as well as percussion. So, I purchased 4 very long mini-jack to RCA cables (one

Figure 4.1: Maria Finkelmeier and Jacob Remington of *Ensemble Evolution* rehearsing the *iPhone* and percussion work *3p3p* by Charles Martin

extra for my *iPad*) and started learning about *RjDj*. I envisioned a semi-improvised composition where each member of the group had a different *RjDj* scene and could control different computer elements of the composition.

After developing some compositional ideas in *RjDj*, I named the work *3p3p*[1] and settled on the available interactions. Each player's screen (shown in figure 4.2) was divided into four, with each quadrant functioning as a button. The upper two quadrants activated computer elements of the composition, for example, a drum synthesiser playing random rhythms, the lower two quadrants activated effects that processed the sound from the *iPhone*'s internal microphone. Each player's phone had different computer composition elements but the same two effects; reverb and a pitch shifting delay effect. The computer compositions used the phone's accelerometer to adjust some variables; for example, the orientation of the phone was able to control the length of notes created from a field recording of cracking ice.

Although it was intended that the players are improvising in this piece with most of the composition work being in the computer elements and interaction, I produced a score which was intended to give some structure

[1] for 3 phones, 3 percussionists

Figure 4.2: The *RjDj* interface for *3p3p*

and variety to the improvisation. A copy of the score, marked up by Maria Finkelmeier, is shown in figure 4.3. The work's first and only performance was in the foyer of *Studio Acusticum* at a lunchtime concert at *Ensemble Evolution*'s own *Piteå Percussion Repertoire Festival*, in March 2011. The work was well received by the audience as well as the other members of *Ensemble Evolution*. Unfortunately, the performance wasn't recorded; however a recording of our final rehearsal is included with this thesis[2].

Although *3p3p* was performed only once, it formed an integral part of my exploration into mobile computer music. The concept - three *iOS* devices connected with simple headphone extensions speakers - was proved to work at least as a prototype performance. It was notable that in the week leading up to the performance the group didn't even *think* about the work, since we were so overwhelmed with running our festival. However, the setup was so simple that we were able to perform well with only a minor soundcheck. The *RjDj* scenes didn't go to waste either - as the first significant composition I had produced in *Pure Data*, they formed a core of ideas and programming techniques that I drew upon for the other works discussed in this project. Overall, this experience helped to define the direction of my work towards this thesis.

[2]see recording of *3p3p* rehearsal, video index 1 (appendix B.2)

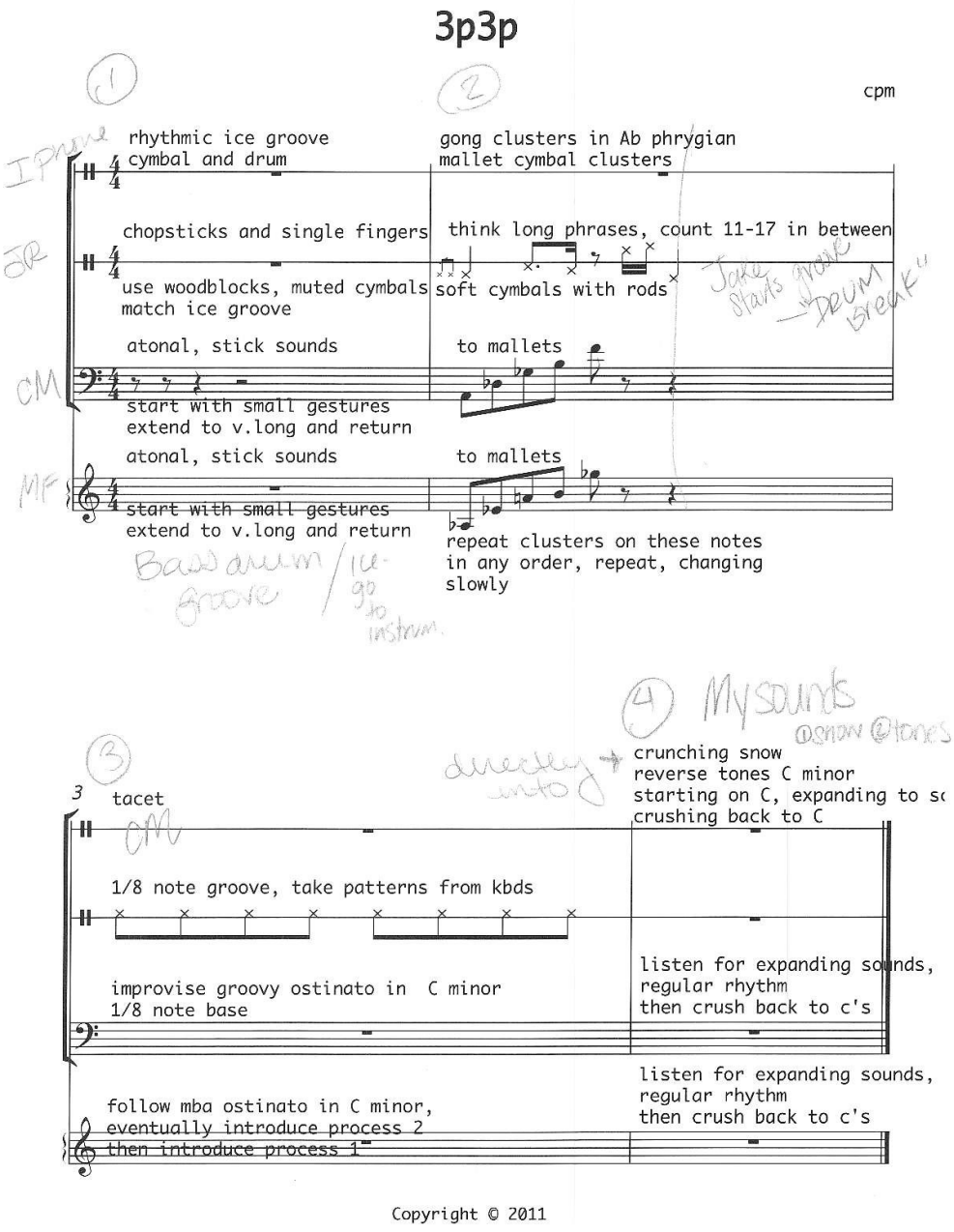

Figure 4.3: A marked up score for *3p3p*

4.2 *Snow Music*: A Tested Development Process

Almost a year after first developing *3p3p* with *Ensemble Evolution*, we decided to create another work together using *iOS* devices along with acoustic percussion instruments. This creative endeavour was undertaken as part of this research project with the particular goal of studying the "shareability" of mobile computer instruments and the process of jointly discovering a performance practice for a new computer instrument - in other words, to address the second, third and fourth research questions from section 1.3.2.

In order to fully capture the creative process, every rehearsal, meeting, and the series of initial public performances was video recorded. A complete list of recorded events is given in appendix A. Rehearsals took place throughout February 2012 in Piteå while the public performances occurred in March 2012 in Australia as part of *Ensemble Evolution*'s *Solstormen* tour.

Qualitative analysis of this video documentation was performed through a process of "coding"[3], connecting and noting key-concepts to events occurring in the video. The events from conversations and performances could then be organised by key-concept and connections thus made between multiple meetings and rehearsals in this process. Figure 4.4 shows an excerpt of the coded transcript of rehearsal 2, while figure 4.8 shows an excerpt of the coding document for performance 9 at Melbourne Conservatory.

The rehearsal process does not capture the actual development (i.e. programming) of the computer music instrument. The information about this process comes from a number of process diary entries I made over the rehearsal period as well as explanations about this process I gave to the other members of the group in rehearsals which were captured in the video.

Before looking in detail at the results of the video document, it is helpful to describe roughly the sequence of events. All of the meetings and rehearsals for this project occurred in our rehearsal studio at *Studio Acusticum*, in Piteå. The first meeting was dedicated to planning and my explanation of the idea for the project. The three subsequent rehearsals were marked by changing ideas about the musical content of the work and discovery of how to play the *iOS* devices. At this point, it was agreed that the work would be a free improvisation, *Snow Music*, motivated by the computer sounds with each player using an *iOS* device and a keyboard

[3]The process of coding and deriving meaning from textual data is explained at length in Krüger's handbook, *Ethnography in the Performing Arts* (Krüger, 2008, chap. 4). Many ideas for coding performances and non-verbal interaction came from my supervisor, Stefan Östersjö, who used them at length for his doctoral dissertation *SHUT UP 'N' PLAY! Negotiating the Musical Work* (Östersjö, 2008).

percussion instrument. The next two meetings included visitors: Matteo Spano, Astrid Lindh, Lisa Wagner, and Scott Herring, who improvised with us and experimented with the *iOS* app.

There were three public performances of the work in Australia, all including collaborations with performers outside of *Ensemble Evolution*. The first was at Melbourne Conservatory and included Nat Grant, an improvising percussionist and computer musician focussing on looping and computer augmentation of percussive and found sounds. The second, in *Serial Space*, Sydney, took the form of a group improvisation along with Timothy Constable, Christina Hopgood, William Jackson, Bart Haddock, and Anna Ng. The final performance was included as part of an *iPad* music workshop for high school students at Canberra Grammar School. *Ensemble Evolution* performed with *iOS* devices and percussion instruments while the students used the *Nordlig Vinter RjDj* scene and other *iOS* instruments during the improvisation.

Before beginning the analysis of the rehearsal process, I should note that for simplicity I will refer to sections of continuous playing during rehearsals as performances (rather than run-throughs or any other term); after all, we were performing for ourselves! Performances for an audience will be referred to as public performances when the distinction is necessary. Rehearsals and performances are referred to by number, for example, performance 5 or rehearsal 3. The date and description of each of these events can be found in appendix A and recordings of all of the performances investigated here can be found in the documentation of artistic outcomes in appendix B.

Two of the research questions, shareability and playability, can be addressed by analysis of the artistic process taking place in discussions and rehearsals. The fourth research question, performance practice, must be connected with the performances recorded over the whole process. Since the coding process is different between the verbal discussions in rehearsals and the non-verbal performances, the analysis will be split across the two sections that follow.

4.3 Rehearsing and Developing *Snow Music*

The coding process revealed a thematic split in the discussions we had during rehearsals. A large proportion of the conversation was dedicated in some way to planning - questions like “Should we play again?” and “What instruments should I use?” connect with ideas like “[It’s] super effective just improvising”. Other important themes were problem solving with musical and technical problems, solutions, and suggestions. Finally, it is interest-

```
MF - I had no sense of time! were you on the "and"?
        _musical_problem
CPM - how come your first thought was that I was on "and"??
CPM - I discovered some new things about how to play the app!
        _achievement
CPM - I think there should be a button to play sounds by itself
        _suggestion
MF - like wind sounds or something _suggestion
CPM - something in the background so we can concentrate on
        other stuff _suggestion
MF - I agree
CPM - I think this could be the first level or something.
        _musical_problem
```

Figure 4.4: An example from the coded transcript of rehearsal 2, just after performance 3. Major conversational elements were transcribed while the rehearsals were viewed a number of times. A list of codes were used to note different kinds of problems, suggestions and reactions from the group.

ing to note moments where performers had strong reactions, positive or negative, to certain events.

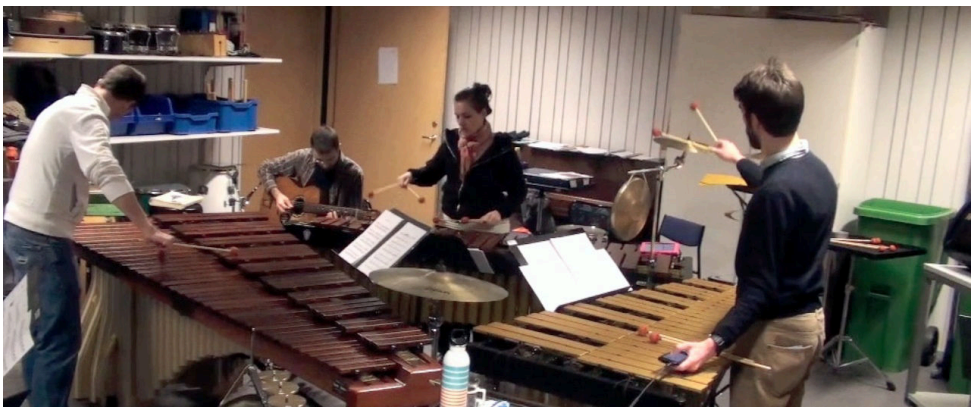

Figure 4.5: *Ensemble Evolution* and Matteo Spano playing in rehearsal 4.

4.3.1 The Rehearsal Process

The main agreement from the initial planning meeting was that this piece would be a successor in some way to *3p3p* performed almost a year before. I would take responsibility for creating the *iOS* component of the piece and have a degree of control over the musical direction, but much of the music would be improvised and many creative decisions would be made during rehearsals with the group. In the days following this meeting, I decided on a direction for the *iOS* component. In the time since working on *3p3p*, *RjDj* had become less attractive, due in part to the developers moving onto other projects and the development tools becoming out of date. Simultaneously, I was aware of increased interests in other tools for creating *iOS* computer music applications such as *iSuperCollider* and *libpd* (described in section 2.4).

My process diary from this time records my decision: "*libpd* is definitely the way to go." Using *libpd* for this project had the potential to allow a more rapid process of updating the app on multiple devices, essential for testing and working with the ensemble. Another advantage of *libpd* was that a native *iOS* app using this library could take full advantage of the *iPad*'s large touch screen. Whereas at the time of *3p3p* the group mainly had access to *iPhone*s, the group now had two *iPad*s and fewer (working) *iPhone*s, a fact discussed in our early rehearsals, with the potential to access more *iPad*s in Australia. This change gave me the idea to use the *iPad*'s touch screen to emulate a tactile percussion instrument. Inspired by the natural environment and a percussion piece for "glockenspiel and amplified snow"[4], I began with the idea of emulating a bowl of snow that could be manipulated by the performer's hands. I presented a prototype of this idea to the group at the first rehearsal. The name of the app became the name of the piece, *Snow Music*.

Rehearsal 1 brought our first confrontation with the technical setup for this project beginning with the process of installing the app on each device. My *iPad* and *iPhone* already had the app installed, but it needed to be setup on Maria's *iPad*. In the first rehearsal this process took a few extra minutes as a special process is required to enable an *iOS* device for development. Subsequent upgrades to the app were faster but still required the device to be connected to my computer via USB. We decided that Maria would use her *iPad*, and Jacob would use mine while I would perform with my *iPhone* using the same app[5]. Although we thought of borrowing another *iPad* for

[4] *Syntax of Snow* by Matthew Burtner (2011).

[5] A "universal" *iOS* app can present a different interface depending on whether it is installed on an *iPhone*, iPod touch or *iPad* but in the case of *Snow Music* the only

our performances in Australia as the rehearsals, we became used to this setup and it was carried over to the public performances.

In rehearsal 1 we experimented with a new amplification setup for the *iOS* devices. For *3p3p* we had used a mixer to connect three devices to one loudspeaker, but for this rehearsal we directly connected each of the three devices to three powered loudspeakers positioned behind each player using long audio extension cables. This setup is rivalled in simplicity only by the use of the *iOS* devices' internal speaker or perhaps by a battery powered speaker (as used by *MoPho*[6]). In our case, it seemed necessary to use amplification in order to compete with acoustic instruments. Using three speakers significantly enhanced our ability to discern each player's contribution to the ensemble, a fact which I commented on in the second rehearsal. Unfortunately, we weren't able to travel with the loudspeakers and so our public performances were made with stereo speaker systems available at the venues where we performed. In these circumstances, the devices were panned full left, centre and full right, but even then, the same level of separation wasn't possible.

In rehearsals 1 and 2 we simply used any available surface to place the *iOS* devices including the keyboard percussion instruments that were playing. Maria and Jacob almost always played the *iPad*s while they were resting like this, whereas I often picked up the *iPhone* to play it one or two handed. In the performances it seems that Jacob and Maria were more comfortable placing their *iPad* on the marimbas we used, while I had some problems finding a place to put the *iPhone*. Perhaps the *iPad*s, with their more substantial size and weight seemed more secure placed on an instrument, while I was always worried about the *iPhone* sliding off, pulled by the weight of the audio cable. The *iPad*s also have more substantial cases, and seem unlikely to damage the instrument. In these performances, Jacob and Maria played marimbas, significantly bigger instruments than the 3 octave vibraphone I used. Perhaps the loss of a few marimba notes to the *iPad* seems less consequential to the improvisation than the same area lost on a vibraphone.

The decision about what percussion setup to use in the piece was made in rehearsal 1. For performance 1 in this rehearsal, the first attempt at using the *iOS* app, we used non-keyboard percussion instruments[7]. We all picked a small collection of "interesting" instruments - crotales, woodblocks, a tom tom, temple bowls, spiral cymbal - and played them in a free improvisation

difference was the size of the touch area on the screen which was simply scaled down to fit the *iPhone*.

[6]Stanford CCRMA's Mobile Phone ensemble (Wang et al., 2008).

[7]see performance 1, video index 3 (appendix B.2)

with the *iOS* app. In performance 2 we played on keyboard percussion instruments - two marimbas and vibraphone - and used a semi-composed piece of mine called *A nice theory*, which provided the melodic material.[8]

Immediately, we agreed that the keyboard setup seemed to work better with the snow sounds from the app. I commented that perhaps the non-keyboard setup would work better with "some scheme for why we choose those specific instruments"[9] to allow us to contrast the snow sounds with some specific tone colours from other instruments. In any case, the keyboard instruments were the focus of our setup for other pieces on our upcoming tour, and so we decided to use them as the core of our setup along with the *iOS* devices with *Snow Music* and some cymbals and gongs that we would be able to take on tour with us.

As was just mentioned, our process of deciding a musical structure for using the *Snow Music* app with the keyboard percussion instruments began with *A nice theory*. However by the end of rehearsal 2, there was an atmosphere of dissatisfaction with this plan. While the melodic material was pleasant, the combination of it with the *iOS* app felt arbitrary, especially given the limited sonic palette of the app at this point. The suggestion was made to add "another element, more sounds", perhaps recognisable sounds like wind or footsteps so that we could "start with something identifiable and then play with the sound"[10].

The result of this discussion was an updated app ready for the next rehearsal featuring new snow manipulation sounds (including footsteps) and three generative background sound players: a "windy" snow sound[11], slowly evolving cymbal phrases, and clusters of bells that peal in a random order of notes from the C aeolian scale. The interface is shown in figure 4.6.

In rehearsal 3 we experimented with this updated app, trying a free improvisation motivated by the "bells" background soundscape[12]. This performance was noticeably more confident and varied than the previous attempts. After the performance Maria remarked "we should keep it like this" and "I like having no parameters"[13], referring to the lack of any kind of score for the piece. In fact, the piece did have parameters, our improvisation was completely motivated and structured around using the sounds available in the *iOS* app. Since the work was aimed at developing and demonstrating

[8] see performance 2, video index 5 (appendix B.2)

[9] see rehearsal 1, excerpt 2, video index 7 (appendix B.2)

[10] see rehearsal 2, excerpt 3, video index 11 (appendix B.2)

[11] actually the sound of Jacob and myself pushing around very loose, dry snow with our hands

[12] see performance 4, video index 13 (appendix B.2)

[13] see rehearsal 3, excerpt 2, video index 14 (appendix B.2)

the computer sounds, this was suddenly much more comfortable than the awkward pairing of the computer sounds with a different composition[14]. In following rehearsals and collaborations with other players, we became comfortable explaining that the "sound (of the app) dictates what the pieces is going to be about", the "sound of Piteå" in winter[15].

4.3.2 Problems

> Is there a way to make the loud stuff die off quicker? (Jacob, rehearsal 3[16])

A number of problems came up repeatedly over the course of the rehearsal process. Most of the technical problems related to the result of an interaction with the *iOS* app not aligning with the player's expectation of what would happen. This mainly occurred in the first rehearsal where Maria remarked "the interaction was throwing me off a bit"[17] or in the second where she simply evaluated an attempt to play: "FAIL"[18]. The unexpected reactions to different kinds of gestures exacerbated another problem - managing the expected volume of the *iOS* devices coupled to the loudspeakers.

The musical problems with the *Snow Music* app fell into two categories but were basically related to the clarity of expression that was possible with the application. First was the inability to express clear rhythms with the devices. Early in the process we all were attempting to play rhythms with a repeating pulse on the devices as well as ambient sounds in free time, but at the end of performance 3, Maria asked me "were you on the 'and'?"[19]. At that moment it was clear that whatever I had been trying to express with the app was not coming across. The second problem was to do with the timbral clarity of sound produced by the *iOS* devices. In rehearsal 1, Maria compared the snow sounds to "radio static" and Jacob commented that the app felt "limited" in rehearsal 2[20]. The sounds created by the app at that time just "sounded too similar", different gestures produced similar

[14] *A nice theory* wasn't thrown out, by the way. It was put to use for its original purpose, as a piece for working with student groups who may not be comfortable improvisors. The first public performance of this work also occurred in Australia in March 2012 by *Ensemble Evolution* and students from Melbourne Conservatory.

[15] Charles, rehearsal 5

[16] see rehearsal 3, excerpt 1, video index 12 (appendix B.2)

[17] see rehearsal 1, excerpt 2, video index 7 (appendix B.2)

[18] see rehearsal 2, excerpt 1, video index 8 (appendix B.2)

[19] see rehearsal 2, excerpt 2, video index 10 (appendix B.2)

[20] see rehearsal 2, excerpt 3, video index 11 (appendix B.2)

Figure 4.6: The *Snow Music* app's interface on an *iPad*. Tapping and sliding on the "snow" area directly controls the manipulation and playback of snow sound files. The three switches in the corners start and stop generative background sounds and the information in the top left corner is to help development.

outputs and it wasn't obvious how to coax interesting sounds out of the devices.

These problems are related to the disconnect in computer based instruments between the performer's actions and the sound, a central topic of research in computer music. In most acoustic instruments, the performer's actions directly activate the part of the instrument that produces sound, for example a marimba mallet strikes the bar that vibrates and sounds. Computer instruments have a great deal of separation between the performer's input, in this case touches on the *iPad* screen, and the sound produced by a synthesis engine in the software. As Evens remarks, there is "a layer of abstraction to an electronic instrument, a degree of separation between the applied force and the resultant sound." (Evens, 2005).

4.3.3 Solutions

Fortunately, these problems could be addressed over the process of the rehearsals. In some cases, all that was needed was some more explanation from me, as my ideas about how to program the interaction between the performer's gestures on the touch screen and the sound output were rapidly evolving during this process.

The interactive concept came down to: "use percussion-y technique"[21]. My idea was that common techniques for using hands to play percussion instruments - taps, finger rolls, scraping and rubbing - would also work on the *iOS* devices. Another simple explanation was to use the hardware volume control on the *iOS* devices[22] continuously through the performance to help control dynamics and adjust for any unexpected volume levels from the loudspeaker. Finding techniques like these were an important part of developing a performance practice with the *iOS* devices.

The musical problems were addressed through updates to the app made in between rehearsals and also through suggestions and inspiration from the other members of the group. One strategy from our discussions was to "try some more exact sounds to hook in with melody and rhythm", where "exact", perhaps, means more representative of the source. In the first rehearsal, Jacob and Maria suggested other characteristic sounds of Piteå

[21] see rehearsal 1, excerpt 1, video index 4 (appendix B.2)

[22] For those holding out from the Apple way, all *iOS* devices have four hardware controls: a home button on the face that causes the devices to exit the current app and return to the home screen, a sleep/wake button on the top edge that sends the device to sleep or wakes it up, a switch on the right edge to mute the device (i.e. stop it ringing) and a volume control on the left hand side.

like the sound of footsteps on packed snow or the wind that blows around our apartment complex.

With the chance to update and improve the app in between rehearsals, I was able to implement these suggestions or achieve a similar result. I was also able to refine the interaction between the touch gestures and the sound output which I explained to Jacob, Maria and other collaborators as "direct control over the sound"[23]. The idea was to emulate simple percussion instruments, like bells or woodblocks, that only sound when struck or otherwise manipulated. My intuitive feeling was that we should be able to translate our musical skills more easily to the *iOS* devices if many of the available sounds were created in a direct way. This approach was vindicated when Maria suggested in the third rehearsal that "with the three of us, it's pretty easy"[24] to maintain more or less continuous soundscapes, without relying too much on continuous drones or background sounds from the *iOS* devices.

Another concept of interaction that I explained to the group was the idea that sounds are "supposed to always be a bit different"[25], in other words that repeating the same gesture can produce a changing sound rather than precisely the same sound multiple times. In some ways this is contradictory rather than analogous to real interaction with percussion instruments, but common-place in electronic instruments. A synthesiser, for example, might have a low frequency oscillator continuously varying a low cut filter, so that pressing the same note repeatedly results in changing sounds. In the case of *Snow Music*, tapping the same place on the screen might play sound material taken from different parts of a sound file, so that the sound is never exactly the same.

4.3.4 Reactions

When analysing the video documentation of the rehearsals it is interesting to recall the reactions that we each had to different circumstances. It is encouraging to realise that the most common reaction during the rehearsals was a sense of achievement after playing something together. It is very clear that our group has a collective passion for creating music and the feeling of making something new and improving as improvisors is joyful and worth celebrating.

One reaction that seemed not to appear in the *Snow Music* rehearsals was 'confusion'. I had a strong memory of the group being confused about

[23] see rehearsal 3, excerpt 1, video index 12 (appendix B.2)
[24] see rehearsal 3, excerpt 2, video index 14 (appendix B.2)
[25] see rehearsal 1, excerpt 1, video index 4 (appendix B.2)

how to approach *3p3p* in 2011, something that I directly asked the group in our initial meeting. Maria recalled the feeling of "What the hell is going on?"[26] with our rehearsals leading to the performance of *3p3p* but we didn't experience it in the same way with *Snow Music*. Perhaps the most likely explanation is that we have developed a much stronger group dynamic since that time as well as more experience with improvisation and working together on composition projects. In early 2011 we might have kept quiet about potential problems or unclear ideas whereas during the *Snow Music* project we were more likely to confront each other honestly about issues encountered during rehearsals.

Another positive reaction was the sense of interest we felt in unexpectedly cool interactions and musical results. When the *iPad* app was updated each rehearsal, Maria and Jacob noticed the improvements, Jacob commented "I love how squishy [the snow sounds] are now"[27], and got more interested in using the app. Our collaborators and visitors were immediately interested in the app and what kind of sounds it could create.

Negative reactions were, thankfully, few and far between in the rehearsals and outnumbered by positive. But when they occurred they tended towards frustration. The problems of confusing or unexpected results to certain interactions and the musical limitations of the app, as discussed previously, were a cause of frustration during rehearsals. Maria's comment, "FAIL"[28], at the start of performance 3 sums up her feeling when the tapping and sliding on the touch screen didn't seem to create any sound.

4.4 Performances and Experiences with *Snow Music*

Understanding the performances that took place throughout this project presents different problems than looking at the rehearsals. First of all, since the musical content of the project turned out to be free improvisation, most of the techniques and musical applications of the *Snow Music* app emerged naturally during the rehearsal process and were not prescribed by a composer. Secondly, coding performances is a more difficult process than coding rehearsal discussions since the source material has no verbal content that can be easily transcribed and classified.

For these reasons, to understand the performance practice that we developed for *Snow Music*, my approach was to pick three representative performances from different stages of the process. The first, performance 2, was

[26] see meeting excerpt 1, video index 2 (appendix B.2)

[27] rehearsal 3

[28] see rehearsal 2, excerpt 1, video index 8 (appendix B.2)

Figure 4.7: *Ensemble Evolution* and Nat Grant performing *Snow Music* at Melbourne Conservatory.

in our first rehearsal using the *iOS* app and three keyboards using melodic material from *A Nice Theory*. The second, performance 5, was a free improvisation in our studio along with guitarist, Matteo Spano. The third, performance 9, was in a public concert in Melbourne, Australia, with Nat Grant performing on laptop. These performances were chosen to appreciate the curve of exploring the *iPad* app and to find out how it complemented the acoustic percussion instruments.

To recap, the final *iOS* app for *Snow Music* had two main functions. The first was a touch interface that creates snow sounds when the the screen is tapped or swiped with a finger. The dynamic of tapped sounds can be controlled by the distance of a tap from the centre of the screen (centre is the quietest sound and edge is the loudest). The dynamic of swiped sounds corresponds to the speed of the swipe, where faster is louder. The second function is a set of three background soundscapes, algorithmic process that produce phrases of notes in free rhythm[29]. The three soundscapes are of bells, cymbals and a swooshing, wind-like snow sound. The bells are set to use notes only from the C aeolian scale while the cymbals and snow sounds

[29]The background soundscapes are designed to play phrases of notes without a repetitive rhythm. In short, an algorithmic process chooses a length for the phrase between 1 and 7 notes, intervals between the notes between 50ms and 1049ms and then an interval to wait before starting the next phrase between 1 and 8 seconds. When notes are sent to bell synthesisers, a pitch is chosen from the C aeolian scale, while notes sent to the cymbal and snow synthesisers are assigned a random pitch. Part of the fun of computer music is experimenting with algorithmic processes like these that use randomness in pitch and rhythm in a musical way. All of this work is done in *Pure Data* on my computer and then compiled into the *Snow Music* app that runs on the *iOS* devices.

are indeterminate but changing pitch. The overall dynamic of the sounds can be controlled using the *iOS* devices' hardware volume controls. In the first rehearsal, only a prototype of the snow sounds was available, but for the other two performances discussed here, all the sounds were available.

```
## 2012-03-12 - performance at Melbourne conservatory

0:00 snow steps collage _snowTapSparse _sparseTexture
        _arrhythmicPlaying
0:05 clicking from nat's shaker
0:10
0:15 some snow accents _snowTapRhythmic
0:20 nat delay and detune shaker
0:25
0:30
0:35 cpm snow sliding _snowSlidingFree
0:40 1 cymbals _snowCymbals
0:45
0:50
0:55 maria rhythmic snow steps and sliding _snowTapSparse
        _snowSlidingFree _arrhythmicPlaying
1:00 jr rhythmic snow steps _snowTapRhythmic
1:05 mf snow slides _snowSlidingFree nat mbira notes _newIdea
1:10 cpm rhythmic slides _snowSlidingRhythmic
```

Figure 4.8: An example of the coding document for the performance of *Snow Music* at Melbourne Conservatory. A list of time codes was prepared for performance with a line every five seconds. Watching the performance several times, I filled in codes (the words starting with "_") to note different aspects of the performance practice.

4.4.1 Techniques

The first concern when performing with the *iOS* devices was the technique we needed to actually play them as instruments. The process of exploring different playing techniques is related to the affordances of the app and resulted in the musical application of the app in our piece. Since all the interactions for the *Snow Music* app occurred through the touch screen

we needed to use skin contact to activate it[30]. Although it's possible to hold mallets in our hands and to touch the *iOS* devices with our little fingers or the heel of our hand, we generally played the *iOS* devices without simultaneously trying to hold mallets. This encouraged us to also play the keyboard percussion instruments with our fingers, an intimate but striking sound and a technique that we adopted for the opening of the piece. It also turned out to be possible to hold mallets in one hand and play the *iOS* device with the other.

One of the limitations of the *iOS* app was in expressing clear rhythm. In performance 2, the sounds produced by the app were indistinct and the connection between the performers' gestures and the sound was obscure - a fact discussed during the rehearsal. The performers adopted a kind of "finger roll"[31] technique in this rehearsal, relying on continuous sounds due to the unsatisfying singular sounds that were available. In performance 5, this issue had been address in the app and the players were able to produce much more distinctive snow sounds. These sounds however, tended towards free rather than precise rhythm, since the performers could not control the length of tapped notes and had only a limited degree of control over the dynamic of swiped notes.

A good example of experimentation to overcome this was Maria's rhythmic swiped notes from 8:45 to 9:15 in performance 5[32]. By swiping very quickly from side to side on the *iPad* screen as part of an exaggerated gesture she was able to precisely place quite short notes in the context of a clear 16th note groove set down by Jacob on marimba and myself on vibraphone. This demonstrates that there was a musical application for this kind of rhythmic playing and potential in the application but it is interesting that this technique was not explored more fully in performance 9. Although a clear rhythm was "possible", it could be that fine rhythmic expression (e.g. expressing accents or subtle swing feels) was too hard to accomplish with this swiping technique. It would be hard to perform with the rhythmic finesse of a guiro on the *iPad* touch screen even though the technique is similar. The glass touch screen offers little tactile feedback about the speed of a swipe making it hard to use the extremely fine changes in speed, pressure and direction that are required on guiro and many other percussion instruments to express precise rhythms. *iPad* touch screens don't detect pressure very well[33] and probably don't have high enough timing accuracy

[30] *iOS* devices use capacitive touch screens that rely on the electric conductivity of skin to function, so touching them (gently) with a mallet or stick will have no effect

[31] see performance 2, 00:10, video index 6 (appendix B.2)

[32] see performance 5, 8:45, video index 18 (appendix B.2)

[33] A programming technique that uses the changing size of a pressed finger on the

to detect very fine changing speed of swiped gestures even if the software were improved to focus on this kind of interaction.

The players also experimented with activating the snow sounds with extreme gestures in attempts to increase the intensity of the improvisations. For example, Maria used two hands to swipe on the *iPad* screen at 1:35 in performance 5[34]. This interaction made sense, but was not matched by the sound output as the swiping technique only responds to one touch point at a time. This kind of limitation between gesture and sound output limited the performer's explorations and perhaps the degree to which the app was used in performance.

4.4.2 Musical Affordances

The three background sound generators (bells, cymbals and "snow wind") were added to the app in response to the discussions in rehearsals and appeared in performances 5 and 9 but not 2. Musically, these sounds were developments of similar functions in *3p3p* and *Nordlig Vinter*, but in response to those experiences, these were designed to produce notes with sparse, free rhythm and continuously vary the pitch of the sounds. The background sounds were activated by a simple switch displayed on the *iPad* screen; when the switch was on, new sounds were produced and when the switch was off, no new sounds would be produced but the existing sounds were allowed to decay naturally. From the performance videos, it is clear that the musical affordances of these sounds inspired their use during our improvisation. By far the most used of the three was the bell sound. This sound had a clear tonal centre, the C aeolian scale, and a clear texture that cut through other sounds in our improvisation. The group responded to these affordances by using the sound to drive sections of tonal improvisation in free rhythm. Once one player had switched on the bells, the others could easily hear this and respond by going along with that direction and maybe switching on their own bell sound or conversely, consciously resisting that musical direction.

The other background sounds, cymbals and snow wind, were not used as frequently in performances 5 and 9. Where they did appear, their musical function was to create a dense texture that would support various styles of improvisation. The cymbals had a clear and recognisable timbre while the snow wind sound was quite subtle and did not cut through sound of other instruments. The subtlety of the snow wind sound meant that when it was

touch screen can infer information about pressure. For example, the "pressure sensitive" keyboards in *Apple*'s *Garageband* app for *iPad* probably use this technique.

[34]see performance 5, 1:30, video index 17 (appendix B.2)

used it did not have a significant impact on the direction of the playing and it was the least used sound (or inaudible when it was used!). In fact, in performance 9, the cymbal and snow wind sounds were hardly used at all. With a fourth player on laptop, this performance already had a much denser texture than the trio of keyboard percussion instruments and we may not have felt a musical need to activate those subtle textural sounds.

4.4.3 Musical Application

It has been previously discussed that over the rehearsal process the *Snow Music* app developed from being a *part* of another semi-improvised composition into the defining feature of an improvised piece, but how was it used overall in order to define a piece of music that had no pre-agreed parameters except for the instrumentation? Analysis of even the earliest performances reveals that we started the piece by creating a "snow collage" using the snow tapping technique[35]. In the later performances, this element became more well defined and included the wider variety of sounds that were added to the app. In particular, the sound of footsteps in snow activated by tapping the *iPad* are strongly mimetic and gave a distinctive theme to the "snow collages". In these later performances, the "snow collage" was used both to open and close the work.

Apart from these important performance elements, the performers used the snow sounds sporadically throughout the work. Rather than playing the keyboard instruments all the time through the improvisation, the performers used the snow sounds during moments of silence, for example, after playing a soloistic melody. Perhaps the app contributed to the variety of the improvisation in this way, by providing each player with an alternative way to perform in the ensemble that changed the texture of the overall sound.

During the performances, there are clear changes in the intensity of the improvisation, and it is interesting to see what impact the *Snow Music* app had at these times. While there are moments when the app was used to build intensity in the piece, for example, during the "snow collage" at 0:30-1:00 in performance 5[36], significant increases in intensity were usually driven by the keyboard percussion instruments. The *Snow Music* app was, however, used to begin a process of decreasing intensity. An example is my use of the app on my *iPhone* at 7:45 in performance 9 which triggered the closing "snow collage" in that performance[37].

[35] see performance 2, 00:00, video index 5 (appendix B.2)
[36] see performance 5, 00:30, video index 16 (appendix B.2)
[37] see performance 9, 7:45, video index 24 (appendix B.2)

One of the most important aspects of free improvisation is the production of new ideas by the performers that pushes the improvisation in new directions. When investigating the emerging performance practice of the *Snow Music* app, it became important to me to find out whether it was possible to use the app to drive new ideas into the improvisation. In performance 5 and 9, where we are pursuing free improvisation rather than following a compositional idea, new ideas tend to occur around every one to three minutes and were produced mainly by the three members of *Ensemble Evolution* rather than our collaborators. These ideas were usually expressed on the keyboard percussion instruments, but significantly, the "snow bells" background sound could push the performers towards a free rhythmic improvisation around the C aeolian tonality[38]. The touch driven snow sounds, too, could drive the group into a lower intensity improvisation or a "snow collage" as I initiated at the end of performance 9. There may well be a visual element present in this technique. Whereas Jacob and Maria used *iPad*s resting on their keyboards or stands, I was able to hold my *iPhone* up for the others to see. In performance 9, when I created a new improvisational idea using the snow sounds, I held it in my hands. It may be that the sounds are too subtle to properly drive the improvisation unless accompanied by a clear visual indication of the musical intent. This seemed to be easier on the *iPhone* rather than the *iPad*s.

4.5 Discussion

Through analysis of the rehearsal process and the resulting performances of *Snow Music* and *3p3p* a wealth of new information about using mobile music devices has been uncovered. It remains to connect this information with the research questions. Although this collaborative project was designed to address the second research question, the "shareability" of a mobile computer musical instrument, interesting aspects of all four questions have ben uncovered.

4.5.1 Heaviness

The idea of sharing mobile computer music devices with *Ensemble Evolution* was inspired in part by the realisation of how easy such a setup could be, resulting in *3p3p* in 2011. Certainly, the equipment used for *3p3p* and *Snow Music* was simple, elegant and convenient, satisfying the requirements of the question. Particularly in performances of *Snow Music* using one speaker

[38] for example, performance 5, 10:45, video index 19 (appendix B.2)

for each player, only one long audio cable was required for each player. This simplicity greatly contributed to the agility of our rehearsal process. Even in situations where we performed with two speakers, such as performance 9 at Melbourne Conservatorium, this could be accomplished using a compact mixer kept out of sight on the floor of the stage. The entire computer music setup for the ensemble (not counting loudspeakers) could be transported in one backpack.

Such a simple setup fits well into a percussion studio - where setups and instruments are moved around frequently - and perhaps the convenience contributed to our willingness to collaborate with other players and use the *Snow Music* app in free improvisation. When inviting others into the studio, it was very easy to setup the *iOS* devices and experiment playing together. The result was a very positive and inviting creative atmosphere that our group hopes to preserve.

4.5.2 Shareability

Both *3p3p* and *Snow Music* were successful in putting computer based musical instruments in the hands of non-programmers. The performance outcomes from *Snow Music* in particular demonstrate all the performers using the *iOS* devices confidently and musically. An element of this process that I didn't expect was the degree of input that I received from Jacob and Maria during the rehearsals. It is clear from the analysis that suggestions from the group directly connected to many of the technical and musical problems with the app[39]. Importantly, the input from the group helped me to focus my programming in between rehearsals to address specific musical issues with the app and not to worry about unimportant details.

The iterative process of testing new versions of the *Snow Music* app with the group was enabled by my change to *libpd* and native *iOS* development from *RjDj*. Testing and updating *RjDj* scenes was annoying enough to discourage me from distributing new versions to the group, but after the initial setup was complete, it was easy for me to update the *Snow Music* app on the group's *iOS* devices.

As suggested in section 1.1, *iOS* applications are usually created with very simple touch interfaces. The *Snow Music* app was no exception and as our collaborations with other students in performance 8 shows, it was very easy to introduce the app to new players.

[39]see for example, rehearsal 1, excerpt 2 (video index 7) or rehearsal 2, excerpt 3 (video index 11) (appendix B.2)

It was clear from the analysis that the *Snow Music* app became a much more accessible instrument than the *RjDj* scenes in *3p3p*. Part of this was due to simplification, a less cluttered interface, all the players using the same app rather than different scenes, and a simpler compositional process - free improvisation - as well. One important difference was that the *Snow Music* app was designed to act as a computer-based percussion instrument, that would be accessible with basic percussive techniques. Although the generative background sound elements were added later, the core functionality was still situated in a percussive standpoint.

This creative programming process seems to address some of the issues Evens raises with computer music. While Evens claims that "programming is not an open-ended task where one sets out with a desire and improvises along the way" (Evens, 2005, chap. 4), this programming processes *does* appear to be open ended. At the beginning of the process, the only clear desire I had was for an *iPad* based "snow instrument" of some kind. Through experimenting and improvising with different ideas through the collaborative rehearsal process I was able to shape that desire into a useful instrument.

4.5.3 Playability

The really inspiring aspects of the *iOS* devices used in *3p3p* and *Snow Music* were their size, weight and integrated design. Both these pieces were designed around seeing the mobile computer as one instrument in a setup. The change in focus in *Snow Music*, to a percussive gesture based musical instrument, was mostly inspired by the *iPad*'s large touch screen, big enough to think about manipulating and playing rather than just tapping. Both of these affordances were reflected in how the pieces were performed.

The longer rehearsal process for *Snow Music* allowed us to uncover some of the problems encountered when playing these instruments. It was notable that the most frustrating moments in the rehearsals were caused by a disconnect between gesture and result. These issues could be addressed through experience and fine tuning the interaction in the app. It is interesting to note that this issue may not have been uncovered except that the simple interface of the mobile devices invited players to experiment and the percussive perspective of the interaction encouraged them to expect that they could control the sound output in a musical and expressive way.

4.5.4 Performance Practice

The *Snow Music* project in particular resulted in a much deeper investigation into free improvisation performance practice than I had expected. Not only was the concept of combining *iOS* devices with acoustic instruments successful, but it has also become a significant part of my own and *Ensemble Evolution*'s artistic practice. After deciding to pursue free improvisation in *Snow Music*, we discovered that the sound constructed from field recordings in the *Snow Music* app really defined and motivated the piece and helped to give structure and meaning to our improvisation. In truth, this idea had been partly explored in my previous projects combining computer music with percussion and in the work, *Nordlig Vinter*, described in section 3.3, but giving expressive control of the computer sounds to the three members of the ensemble brought this aspect of the performance practice into focus.

Through analysis of the performances, some of the constraints of the *Snow Music* app are made clear. Although many of the sounds are distinctive and allow a degree of precise playing, some were subtle and mainly textural and there were limits to the extent that these sounds could be used in a precise rhythmic context. It is probably not "bad" that some of the sounds had these limits but it is important to understand this and decide what impact it has on compositional process. Perhaps new computer music and interaction techniques could be investigated to remove these limitations. Of particular interest to me was how the *Snow Music* app could be used to express "new ideas" in the free improvisations. I think that in order to keep developing this style of performance and to keep the interest of the other performers in the group, the computer elements need to afford the players more variety of expression of clear musical ideas.

5 Conclusions

This thesis draws together over a year of musical projects performed across three continents. Throughout this period, even while I was attempting to clarify the research, new ideas and inspirations came in from my teachers, colleagues and collaborators. There is, however, a central idea throughout the thesis of how mobile computing devices can connect with percussion. For me, the central goal of this research is to integrate my computer music and percussion practices to meet the challenges of collaborative practice in various performance contexts.

This chapter gives an overview of the findings in chapters 2, 3 and 4 that address the research questions. Also in this chapter the research questions will be reconnected with the artistic motivations of the research project as well as the artistic outcomes set out in chapter 1. These findings and experiences suggest future directions for artistic work and research projects, an important outcome of this project.

5.1 Connecting with the Motivation

The original motivation for this research was to replace the laptop in my percussion and computer setups with a mobile device like an *iPad*. This goal was addressed with the vibraphone/computer interface discussed in chapter 3.

The concept of this mobile computer music system for vibraphone is to reduce the stage presence of the computer by integrating it into the vibraphone frame. This allowed me to focus on playing the augmented vibraphone rather than dividing my attention between the vibraphone and computer setups. A side-effect of exploring this idea was the discovery that a mobile computer could be a more important tool in a percussion setup than just an accompanist and effects processor. My work with *Ensemble Evolution* described in chapter 4, began to explore deeper connections be-

tween the mobile computer and percussionist. In the first project, *3p3p*, the hand-held *iPhone*s can be seen as a special mallet - able to process the sounds of the acoustic instruments and trigger ongoing computer music processes. For *Snow Music*, the *iPad* was seen as one instrument in a percussion setup that was played with fingers taps and scratches.

How do these concepts for percussive practice with mobile devices connect with Tanaka's virtuoso *iPhone* performance in 2010? Tanaka's performance was focussed on the musical world that can be created inside the mobile phone using all the *iPhone*'s sensors and interfaces, a mode of performance close to "laptop music" in the directions of computer music formulated by Newton Armstrong and described in section 2.1. Although *Snow Music* also uses the *iPad* and *iPhone* in this way, the performance is not only focussed on the computer instruments. Moreover, the other artistic projects use the *iOS* devices to augment the acoustic instruments as well, which connect these works with the tradition of music for "acoustic instrument and computer", the third of Armstrong's directions.

The artistic works in the project show a development in the use of mobile devices, from musical counterpoints to percussion, as in *Nordlig Vinter* to a deeper integration with the percussion world, as in *Snow Music* and *3p3p*. The result has been a richer and more varied performance practice using computer music with percussion than I thought would have been possible at the outset of this thesis.

5.2 Achieving the Artistic Outcomes

The artistic outcomes of this project are a system of solo and ensemble compositions for percussion and mobile computer as well as the devices and software required for these works. These outcomes were accomplished through three projects, creating a vibraphone computer music system that was used for performances of *Nordlig Vinter* and two ensemble works with *Ensemble Evolution*, *3p3p* and *Snow Music*. In each project I developed a computer music component, for myself in *Nordlig Vinter*, and for each member of the ensemble in the other two projects.

The vibraphone computer music system includes a set of battery powered microphones that can be attached to the vibraphone with Blu-Tack and an *RjDj* scene designed to be used for accompaniment and effects in *Nordlig Vinter* and for improvisation. This hardware setup was developed up to the prototype stage and used in performances of *Nordlig Vinter* as well as with some other percussion instruments for improvised performances.

Both of the works developed with *Ensemble Evolution* had the basic concept of giving each member of the trio an *iOS* device to use as part of the performance. *3p3p* was a semi-improvised work for vibraphone, marimba and drumset and three *iPhone*s. The *RjDj* scenes running on the *iPhone*s triggered certain background parts to stimulate improvisation among the three percussionists and processed the sound of the percussion instruments. *Snow Music* was a free improvisation for two marimbas and vibraphone where each player used an *iPad* running a "snow instrument" app. The *iPad* could be played as a small percussion instrument, creating sounds from field recordings of snow in Piteå, as well as to produce background soundscapes. While the first work with *Ensemble Evolution* functioned as a proof-of-concept for using *iOS* devices with percussion, the *Snow Music* project was conducted as a collaborative process where all members of the ensemble had input into the direction of the composition and the software development.

All of these project produced research material that enabled significant exploration of the research questions, but *Snow Music* produced the most in depth research data as the collaborative development and performance process was completely video recorded to allow a detailed study. It is interesting to note that all of the works developed in these projects were defined to some extent by the computer music programs developed for the mobile devices. *Snow Music*, in particular, was an improvised work where the structure was strongly influenced by the performance practice we developed for the *iPad* instrument used in this work. For this reason the software created for these works must be considered a part of the artistic outcome as well as the composed elements and improvisational performance practice that were developed.

5.3 Answering the Research Questions

Pursuing the artistic outcomes has provided a range of experiences and answers to the research questions. The works with *Ensemble Evolution* have had more impact on this final summary of the research findings than the vibraphone computer music project. However, all of the projects provide important perspectives on how mobile computer music can work with percussion. In each case the mobile computer fits into the mode of collaboration in a different way. In the vibraphone project, the mobile device was built into the vibraphone itself, augmenting the instrument that I brought to the various duo performance situations. With *Ensemble Evolution*, the *iPhone*s and *iPad*s formed new instruments in each player's setup. Especially for

Snow Music, the collaborative process of composition was also a process of creating the instrument, since these two elements were so intertwined.

5.3.1 Heaviness

All of the artistic projects produced very elegant computer music setups. In the case of *Snow Music* and *3p3p*, the setup was almost as simple as possible - connecting the mobile devices directly to loudspeakers with long audio cables and placing them on the mallet stands and instruments that we already required. The prototype vibraphone pickup interface had an additional level of elegance as it was designed to sit unobtrusively on the frame of the vibraphone.

Assessing the simplicity of these setups requires some kind of comparison with the laptop based setups that might have been used instead. This research project included no experimental comparisons with laptops, but laptops have been used many times in my previous projects. The mobile device setups used noticeably fewer wires on stage since these devices are designed to be battery powered rather than plugged in. They require less secure platforms due to their lighter weight than laptops. Frequently, laptops are used with an external audio interface to increase the quality and quantity of incoming and outgoing audio signals; these were not used with the mobile devices. The vibraphone pickups did not require microphone stands and were light enough to be fixed to the vibraphone frame temporarily with velcro and blu-tack.

On the software side, all of the mobile devices used only one application, rather than a set of software working together as might be used on a laptop. In the *Snow Music* performances, launching the *Snow Music* app presented the simple touch interface and performance could begin immediately. The projects using *RjDj* had a slightly longer setup process, but were not convoluted. In all cases, the touch interface used for the software had very few elements, only four buttons in *Nordlig Vinter* and *3p3p* and three switches and the touch gesture field in *Snow Music*.

Apart from the pleasing aesthetic of these minimal setups, their convenience enabled more artistic productivity - concerts, rehearsals and jam sessions. The *RjDj* based performances were used in concerts with very little time for setup - the pub performance at *Electrofringe* and the lunchtime foyer performance of *3p3p*. *Snow Music* was not only easy to rehearse and perform, but easy to use in collaborative situations with visiting artists in Piteå, and a high school workshop in Canberra. The simple setups we were able to use with these mobile devices gave us confidence to set them up, use them and pack them away in situations without much time. This

meant that they fit well into the percussion studio environment, shared with other students and professionals, where instruments are moved around and packed up throughout the day as required for different rehearsals or performances. This fit enabled much of the development discussed in this thesis and contributed to a creative environment using these devices.

5.3.2 Shareability

The *Snow Music* and *3p3p* projects were successful performances where non-programmer performers used mobile computer musical instruments. The *Nordlig Vinter* scene in *RjDj* allowed broader accessibility to workshop participants in Canberra and to a surprisingly large audience through *RjDj*'s in-app distribution. It is encouraging that these technologies seem to be useful for a wider dissemination of computer musical ideas among performers and listeners.

The touch-screen interfaces available on the mobile devices allowed the concept of "percussive gestures" for controlling the computer instrument in *Snow Music*. This became the core strategy for integrating the computer musical elements into the percussion ensemble. The strong performance outcomes with *Snow Music* demonstrate the performers' confidence in expression on these devices. Rather than reluctantly using the app, the performers embraced it, pushing the limits of musical expression with the simple sounds that were available in that instrument.

The level of engagement with the mobile devices from the group in *Snow Music* led to their collaboration and input in the compositional and development process. The level at which this took place was unexpected for me as it had not occurred to the same extent with *3p3p*. This collaborative process allowed much improvement and as a result *Snow Music* was much more accessible and polished, both technically and musically, than *Nordlig Vinter* and *3p3p*.

The vibraphone computer music system wasn't shared with other performers as much as I had hoped. Although this system was designed so that I could teach others how to build and use it, there wasn't time in this project to pursue this idea. Overall, the projects had success in creating accessible computer instruments and including non-programmers in the creative process of developing the instruments and compositions, which sufficiently addresses the question of shareability.

5.3.3 Playability

The investigations in this thesis focussed on just a few of the affordances of mobile devices. While the size, weight and integrated design of mobile devices had a big impact on the first research question, the visual interface and touch screen affected playability. In response to these affordances, the artistic projects used a number of interface designs to suit the needs of the percussionist performing with these devices.

In the projects using *RjDj*, the available screen size on the *iPhone* was only two thirds of the already small screen. These projects had very simple interfaces using only four buttons to start and stop background sound elements and activate effects. These scenes for *Nordlig Vinter* and *3p3p* were designed to require low attention, so that the performer could focus on playing percussion instruments or reading sheet music. In these instances, the small interface area available in *RjDj* was advantageous as it forced the scenes to have very simply but clearly defined interfaces.

The prototype vibraphone computer music system had a simple microphone system as its main feature. Although this system could enable a deeper connection between the vibraphone performance and computer musical elements, this was not explored past the use of effects.

When developing *Snow Music*, experimentation with the *iPad*'s larger screen inspired its use as a computer instrument controlled with percussive gestures. The collaborative artistic process for *Snow Music* revealed that problems with playability occurred when the performer's gesture was disconnected from the expected result. This issue was addressed through an iterative development process in between rehearsals that was possible because of the close collaborative environment within *Ensemble Evolution*.

5.3.4 Performance Practice

The artistic projects show a curve of performance practices developed to connect mobile computer music devices with percussion. The earlier projects, *3p3p* and *Nordlig Vinter*, focussed on using the mobile devices to play accompanying sounds and effects processing. For *3p3p*, performance of these accompaniments relied on multiple players activating different musical parts while in *Nordlig Vinter* this was refined so that a single button triggered a pre-composed sequence of algorithmic parts. An interesting aspect of the experiences with *Nordlig Vinter* and the vibraphone computer music system was that the simple system encouraged experimentation with other percussion instruments, enabling some of the performances at the *drums + gadgets* concert.

In *Snow Music*, focus turned to the performer directly controlling sounds on the mobile devices. The performance practice for this app was modelled on the simple, but richly sounding, percussion instruments that might form part of an improvising percussionist's setup. The concept of triggering continuous background accompaniments was also included in *Snow Music*, but in a simpler way than in *Nordlig Vinter*.

As the rehearsal process and performances for *Snow Music* show, the performers' improvised practice combined with the unexpected behaviour of the *Snow Music* app resulted in the emergence of a strong identity for *Snow Music* as a musical work. This identity was defined partly by the musical affordances of the app and partly by the collaborative improvised performance practice that *Ensemble Evolution* had developed.

The particular computer music app created for *Snow Music* turned out to have limitations in rhythmic precision and timbral flexibility; however, this discovery was due to the amount of expression and experimentation that the performers put the app through during the rehearsals and performances. An investigation into how the app was used to perform "new ideas" in the improvisations revealed that, although it was used in this way frequently, improvements in possible expression could enable it to become even more useful in performance.

Overall, complementing percussion with these mobile computer music tools has stimulated a great deal of creative expression in *Ensemble Evolution* and my other performances. The most important opportunity that I see from these experiences has been the ability to motivate percussion performances with field recordings. The touch screens of the mobile devices enable these sounds to be controlled with percussive technique and thus integrated into the existing practice of the performers, while the simple and light-weight setups enable these devices to be used in dynamic studio and performance situations. The challenge has been to develop interactive controls for these sounds that make sense to the percussion performers and are also musically useful. To some extent, the collaborative rehearsal process has addressed this problem. Perhaps more importantly it has helped to define this issue so that it can be a focus of energy in future artistic projects.

5.3.5 Exploratory Topics

The two exploratory topics outlined in the research questions concerned trialling a number of technologies for developing mobile computer music devices as well as investigating a number of artistic projects. The latter topic was addressed through the three separate projects, *3p3p*, *Nordlig*

Vinter and *Snow Music* which contributed much insight into the research questions through the different development processes, musical applications and performance scenarios encountered. The topic of trialling different technologies for developing mobile music applications was partly addressed in chapter 2. By defining and articulating a variety of development systems for mobile computer music, it was decided to focus on *RjDj* and native *iOS* application development using *libpd*.

Both *RjDj* and *libpd* rely on *Pure Data* as the underlying computer music programming language. *RjDj* had an initial advantage as it does not require any development tools other than *Pure Data* to create scenes, while creating an app with *libpd* requires an Apple *iOS* developer subscription and a knowledge of *Objective-C*. Although *RjDj* proved to be sufficient for initial experiments with *3p3p* and the *Nordlig Vinter* project, the more advanced touch screen interaction that was explored in *Snow Music* would not have been possible using *RjDj*. In addition, while *RjDj* scenes can be distributed to a wide audience through their in-app store, the process of testing scenes during development is more time-consuming and annoying than the equivalent process of testing native *iOS* applications. Switching to the latter platform allowed a more rapid pace of development during the *Snow Music* project.

5.4 Future Directions

The motivation of this project was to explore ways in which mobile computer music devices can be used with percussion. Over the course of this project, the interest of other performers and collaborators as well as the successful performance outcomes have only served to intensify this motivation.

The investigation and analysis that addressed the research questions has also helped to expose and define the limitations and problems with using mobile devices with percussion. One of the outcomes of this research is the future directions it has revealed for pursuing new artistic projects and research that can address these issues and further explore this interesting field.

5.4.1 Vibraphone/Computer Interface

The vibraphone computer music system was developed to a prototype level. Future projects with this system should be focussed on developing more musical applications - creating new pieces using the system and new soft-

ware tools for improvisation and experimentation. In particular, the works composed so far with this system have not used the microphones for more than standard effects processing. The possibility exists to use pitch and onset tracking to create more interactive computer parts as well as more creative processing to augment the sound of the vibraphone rather than simply complement it. It could also be interesting to try other possibilities for the computer environment such as creating native *iOS* applications rather than *RjDj* scenes or even using other hardware systems described in section 2.3.

If this system were in use for more performances, upgrading the hardware could be a sensible direction. The home-built microphone system could be improved either with higher quality components or some kind of commercial solution. The past year has seen more commercial interest in professional audio hardware to complement mobile devices. *IK Multimedia*'s *iRig Pre*, for example, could replace the simple battery powered microphone preamp that I constructed for this project.

A design consideration for this system was to create it so that it could be constructed by others in a workshop or through tutorials. Although this was not explored during this project, it still remains a goal for this system. Before presenting this system to others, the software and hardware elements may have to be refined.

A broader view of this project could be that it combines handmade electronic musical instruments, with percussion. There are already links between these two artistic practices[1] and so an investigation into current performance practice in "hardware hacking"[2] with percussion could have interesting artistic and research results.

5.4.2 Development with *RjDj*

Part-way through this project, I was convinced that *RjDj* was close to being abandoned as a platform for creating mobile computer music. Although *Pure Data* is a well supported language, the tools for testing and developing *RjDj* scenes had not been updated for newer Apple computers and I could use them only with great difficulty. To some extent this has been resolved but there seems to be a general shift in developer interest from *RjDj* to *libpd* and other platforms.

[1] John Cages's influential percussion works often call for home-made electro-acoustic instruments, such as the wire coil amplified with a phonograph cartridge used in *Imaginary Landscape No. 2* (1942).

[2] An artistic practice expounded by Collins (2009).

It would be a shame to lose *RjDj*. Not only is the audience for *RjDj* scenes very large, but it is much easier (and cheaper) for a beginner to start developing for *RjDj* than to develop a native *iOS* app. This is part of the reason that I chose it for my initial projects.

Despite my newer projects moving to native *iOS* development. *RjDj* still has certain practical advantages. It could be easier in a short term project to distribute a custom computer music app to a large group using *RjDj* than using Apple's development tools. In a class or large ensemble project, *RjDj* may be just right as a distribution platform.

5.4.3 Native App Development with *libpd*

The most exciting and most recent developments in this project were in the *Snow Music* application developed as a native *iOS* application using *libpd* and *Pure Data*. A successful element of the *Snow Music* project was the rapid development process that could be achieved using this platform. Future artistic projects could be modelled on this process and would start where *Snow Music* left off in addressing the limitations that the process revealed in musical expression with the app.

More so than *RjDj*, this mode of development has the potential to create computer music instruments that are strongly tied to percussion performance practice. The research project has shown that it is quite easy to use such instruments as part of a percussion setup. It seems certain that I will use this kind of setup in future works.

The *Snow Music* investigation brought up a very interesting new research question about how the mobile music app could be used in improvisation. The concept of using the app to contribute a "new idea" in an improvisation, to suggest a change in the musical direction, was something that I hadn't considered at the outset of the project but which became important during the analysis. An investigation of this concept could lead to a deeper understanding of improvised percussion performance practice and the creation of expressive and flexible computer musical instruments.

5.4.4 Performance and Composition with Mobile Devices

Studying the rehearsal process of the *Snow Music* project has revealed some of the tensions between the roles of composer, programmer and performer. While this research demonstrates that non-programmer performers can be involved in collaboration on computer instruments, further investigation could reveal more ways to creatively use this kind of collaboration.

It could be that percussion performers, often comfortable with new or invented instruments, can connect well with "digital luthiers" (Jordà, 2005), instrument makers focussed on computer based or electronic instruments.

The projects studied in this research have used two *Apple* devices, the *iPhone* and *iPad*, as mobile computer music platforms. While the *iPad* is more recent than the *iPhone* it is hard to imagine that one would replace the other. For example, the *iPad* would not fit neatly on the frame of a vibraphone to perform *Nordlig Vinter* while the touch interactions for *Snow Music* seem to be more comfortable on the *iPad*'s larger screen. It could be interesting to investigate the effect of the plurality of mobile devices that are now available on computer music performance practice.

5.5 Final Remarks

This research project has investigated the possibilities for bringing computer music into percussion performance using mobile computing devices, a recent focus of development in computer music. Rather than investigate one application, this project looks at a number of creative processes using different hardware, software and musical modalities in order to gain a broader overview.

The research questions were also aimed at a variety of musical processes. Heaviness connects to technical setup and hardware. Shareability and playability connect to creative process, collaboration, and composition. Performance practice connects mobiles devices with percussion and the musical work. The data gathered in the various artistic projects has addressed all of these questions while stimulating and defining new areas for further academic and artistic investigation.

Besides answering the research questions, the general goals of this research have been achieved. From the number and variety of performances, it is clear that mobile computer music devices now form a significant part of my artistic practice in percussion. Not only do I have flexible tools for solo performances or collaborations with other artists, but I have experience developing computer music tools for non-programmer performers in a truly collaborative environment. The success of this project is not only represented by the completed artistic projects but also by the exciting opportunities for new future works that have been enabled and defined by this research.

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A Catalogue of Data for Projects with *Ensemble Evolution*

Entries marked with a * are included in the documentation of artistic outcomes attached to this thesis (see section B.2). Where meetings included rehearsals, run-throughs or performances, these are listed as "performances". Unless otherwise noted, these events took place in the percussion studio in Studio Acusticum, Piteå, Sweden.

2011/03/08 recording of *3p3p* rehearsal (14:44) *

2012/01/30 discussion during rehearsal of the iOS music project (18)

2012/02/14 Ensemble Evolution iOS rehearsal 1 (55)

- performance 1: iPads with percussion (5:50) *
- performance 2: iPads with "A nice theory" for mallet percussion (6:41) *

2012/02/15 Ensemble Evolution iOS rehearsal 2 (17:52)

- performance 3: iPads with "A nice theory" for mallet percussion (8:04) *

2012/02/27 Ensemble Evolution iOS rehearsal 3 (72)

- performance 4: free improvisation with iPads and mallet percussion, starting from "bells" (10:04) *

2012/02/28 Ensemble Evolution iOS rehearsal 4 (52)

- performance 5: free improvisation with iPads and keyboards, with Matteo Spano (acoustic guitar)(11:56) *

- performance 6: free improvisation with iPads and keyboards, with Matteo Spano (amplified acoustic guitar) (9:10) *

2012/03/03 Ensemble Evolution iOS rehearsal 5 with Ensemble Evolution, students and visiting artists. (33)

- performance 7: Ensemble Evolution improvisation with iPads and keyboards (8:35) *
- performance 8: collaborative improvisation with students at LTU and visiting artists (6:53) *

2012/03/12 performance 9: *Snow Music* at the Melbourne Conservatory (9:44) *

2012/03/15 performance 10: *Snow Music* group improvisation with Ensemble Evolution and friends at Serial Space, Sydney (14:06) *

2012/03/21 Workshop in iPad music with high school students at Canberra Grammar School (52)

- performance 11: ensemble evolution play *Snow Music* and class use *Nordlig Vinter* (6:20)
- performance 12: class use two RjDj scenes (8:20)
- performance 13: class use Garageband instruments and Evolution use *Snow Music* app (8)
- performance 14: class use Garageband instruments and percussion (4:15)

B Documentation of Artistic Outcomes

The documentation of artistic outcomes can be accessed on discs or electronic files provided with this document. All of the documentation can also be accessed online using the provided links.

B.1 Work in Progress Recording of *Nordlig Vinter* for Percussion and *iOS* Devices

All music by Charles Martin. Vibraphone - Charles Martin, Marimba (tracks 1, 3, 4) - Christina Hopgood, Marimba (track 6) - Anders Åstrand. All computer accompaniment performed on iOS devices using Pure Data and RjDj. Post production performed in Logic Studio. The demo album can be played at `http://soundcloud.com/charlesmartin/sets/nordlig-vinter/`.

Track Listing:

1. Walk on a white path (marimba, vibraphone)
2. Ice Drum (iPhone, vibraphone)
3. Snow Bells (iPhone, marimba, vibraphone)
4. The Trees are Frozen (marimba, vibraphone)
5. Clusters (iPhone, vibraphone)
6. Footprints in Snow (marimba, vibraphone)

B.2 Video and Audio Recordings of *Snow Music*

All music by Charles Martin. Main percussion performers were Charles Martin, Jacob Remington, Maria Finkelmeier. Extra collaboration was from Matteo Spano (guitar), Astrid Lindh, Lisa Wagner, Scott Herring, William Jackson, Yvonne Lam, Bart Haddock, Timothy Constable, and Christina Hopgood (all iPad and percussion).

There are two methods for viewing these recordings. Firstly, video files from each event are included with this document and can be played back using *Quicktime*[1] or *VLC*[2]. Some files include chapter markers to skip to certain points in the performance that are discussed in the thesis[3]. The second method is to view the events online through the *YouTube* links given below. The *YouTube* videos are "unlisted" and can *only* be accessed through these links.

Index of video recordings:

1. 2011/03/08 - recording of *3p3p* rehearsal (Piteå, Acusticum Percussion Studio) (13:42) (Audio only, with images from the development process.) `http://youtu.be/vJfFVxCJGZE`

2. 2012/01/30 - meeting - excerpt 1 - reminiscing about *3p3p* (1:14) `http://youtu.be/cwz-SIZXMFw`

3. 2012/02/14 - performance 1: iPads with percussion (5:50) `http://youtu.be/DpvZh7An3zM`

4. 2012/02/14 - rehearsal 1 - excerpt 1 - Using percussion techniques (2:03) `http://youtu.be/bumNtuzx19g`

5. 2012/02/14 - performance 2: iPads with "A nice theory" for mallet percussion (6:41) `http://youtu.be/W091aaKSIU4`

6. performance 2: 00:10 - Charles uses *Snow Music* "finger roll"

7. 2012/02/14 - rehearsal 1 - excerpt 2 - Exact sounds and schemes for choosing instruments (2:29) `http://youtu.be/Ixbr4NvyaJE`

[1] http://www.apple.com/quicktime/download/

[2] http://www.videolan.org/

[3] Chapter markers in the video files can be accessed with *Quicktime* or *VLC*, more details can be found in the documentation for these applications.

8. 2012/02/15 - rehearsal 2 - excerpt 1 - FAIL. (1:21)
   `http://youtu.be/R5S5H_i8Zvc`

9. 2012/02/15 - performance 3: iPads with "A nice theory" for mallet percussion (8:04) `http://youtu.be/cw1CWhbvoaY`

10. 2012/02/15 - rehearsal 2 - excerpt 2 - Were you on the 'and'? (0:24)
    `http://youtu.be/tO4YVX-o-vY`

11. 2012/02/15 - rehearsal 2 - excerpt 3 - feels limited, adding structured sounds (2:01) `http://youtu.be/tAew3V3zFDo`

12. 2012/02/27 - rehearsal 3 - excerpt 1 - is there a way to make the loud stuff die off (1:32) `http://youtu.be/NFoFqwMdJDk`

13. 2012/02/27 - performance 4: free improvisation with iPads and mallet percussion, starting from "bells" (10:04)
    `http://youtu.be/L9jgDpybqbQ`

14. 2012/02/27 - rehearsal 3 - excerpt 2 - with the three of us (2:14)
    `http://youtu.be/S_TDkD1Vmls`

15. 2012/02/28 - performance 5: free improvisation with iPads and keyboards, with Matteo Spano (acoustic guitar)(11:56)
    `http://youtu.be/MWicLWySxdI`

16. performance 5: 00:30 - "Snow Collage"

17. performance 5: 01:30 - Maria two hand *iPad* swipe

18. performance 5: 08:45 - Maria swipes precise *iPad* rhythms

19. performance 5: 10:45 - "Snow bells" improvisation

20. 2012/02/28 - performance 6: free improvisation with iPads and keyboards, with Matteo Spano (amplified acoustic guitar) (9:10)
    `http://youtu.be/VWpQflvolIM`

21. 2012/03/03 - performance 7: Ensemble Evolution improvisation with iPads and keyboards (8:35) `http://youtu.be/L_xqTxD6-Bg`

22. 2012/03/03 - performance 8: collaborative improvisation with students at LTU and visiting artists (6:53)
    `http://youtu.be/zlIOJyb2u8Q`

23. 2012/03/12 - performance 9: *Snow Music* at the Melbourne Conservatory (9:44)`http://youtu.be/Vz5aQxc_jlE`

24. performance 9: 7:45 - Charles triggers closing "Snow Collage"

25. 2012/03/15 - performance 10: *Snow Music* group improvisation with Ensemble Evolution and friends at Serial Space, Sydney (14:06) (Audio only, with images from the concert.)
`http://youtu.be/ypxhD_GwSqc`