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DiskPlay: Evaluation of an Augmented Reality Turntable for Musical Performance

Diploma Thesis at the
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Aachen, April 2013
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Abstract

With the introduction of digital vinyl systems it was possible to manipulate the playback of digital audio files using a traditional turntable. Generic timecode vinyls provide precise controls and offer an alternative to DJs that like to perform with records. Because digital vinyl systems use one generic timecode record, information that was provided by the traditional vinyl was lost. Since DJs have to look at the computer screen to get information, digital vinyl systems led to the separation of control and information.

To provide information on the record again, DiskPlay was proposed. Features of traditional records should be visualized on the record using the information that digital media provides. Additionally, DiskPlay should add features only provided by software.

We implemented a prototype incorporating a projector that displays the DiskPlay visualization on a record. It features a general song overview, a waveform display and cuepoint markers. The complete software package consists of three components: An infoBroadcast Quartz Composition sends out information from the host DJ software. The Cue-Point-Feed application recognizes the cuepoints set in the host software. Finally the DiskPlay application visualizes the information received by the other components.

An online survey was set up to gather general information on DJing and digital vinyl systems. The survey showed that DiskPlay is an acceptable system for DJs and that focus switches between screen and turntable are considered a problem. Additionally, four professional DJs were invited to take part in a lab-study, to analyze their behavior with turntables and DiskPlay. This resulted in an overview of interaction techniques with turntables and the conclusion that beatmatching is easier using additional visual aids.

Überblick

Seit der Einführung von Digital Vinyl Systems ist es möglich, die Wiedergabe von digitalen Audio-Dateien mit einem herkömmlichen Plattenspieler zu steuern. Digital Vinyl Systems verwenden generische Timecode-Platten. Diese bieten eine präzise Steuerung und sind daher eine echte Alternative für DJs, die mit Schallplatten arbeiten. Allerdings gehen durch sie Informationen, die von traditionellen Schallplatten bereitgestellt wurden, verloren. DJs müssen auf den Bildschirm schauen, um Informationen zu erhalten, was zur Trennung von Steuerung und Information führt.

Um Informationen wieder auf der Platte zu bringen, wurde DiskPlay vorgeschlagen. Mithilfe digitaler Medien sollen Merkmale traditioneller Schallplatten auf Timecode-Schallplatten visualisiert werden. Zusätzlich soll DiskPlay um Funktionen erweitert werden, die nur in Software möglich sind.

Ein Prototyp wurde implementiert, der, mit einem Projektor ausgestattet, die DiskPlay Visualisierung auf die Schallplatte projiziert. Die Ausgabe beinhaltet einen Überblick über das Lied, eine Wellenform und Markierungen für Cuepoints. Das Software Paket besteht aus drei Komponenten: Die Info-Broadcast Quartz Composition verschickt Informationen der DJ Host Software. Die Cue-Point-Feed Anwendung erkennt Cuepoints, die in der Host Software gesetzt wurden. Schließlich visualisiert die DiskPlay Anwendung die erhaltenen Informationen.

Durch eine Online-Umfrage wurden allgemeine Informationen über DJing und Digital Vinyl Systems erhoben. Die Umfrage machte deutlich, dass DiskPlay eine akzeptable Alternative für DJs ist, der Fokuswechsel zwischen Bildschirm und Plattenspieler jedoch als Problem wahrgenommen wird. Zusätzlich wurde eine Studie mit vier professionellen DJs durchgeführt, um herauszufinden, wie sie Plattenspieler und DiskPlay bedienen. Hieraus geht eine Übersicht von Interaktionsmöglichkeiten hervor. Darüber hinaus wurde festgestellt, dass Beatmatching einfacher ist, wenn zusätzliche visuelle Hilfen genutzt werden.

Acknowledgements

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I want to thank Prof. Dr. Jan Borchers and the whole Media Computing Group for giving me the opportunity to write my thesis at their chair, providing me with the hardware and feedback I needed and introducing me to HCI.

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Conventions

Throughout this thesis we use the following conventions.

Text conventions

Definitions of technical terms or short excursus are set off in coloured boxes.

EXCURSUS:
Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition:
Excursus

Source code and implementation symbols are written in typewriter-style text.

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The whole thesis is written in American English.

Download links are set off in coloured boxes.

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Chapter 1

Introduction

Since Francis Grasso started experimenting with beatmatching in 1969 (Broughton [99]), DJ'ing has come a long way. With constant innovation and the will to set themselves apart from others, DJs have become performers from music players.

New devices were introduced

To introduce new means of performing, DJs needed to create their own set of new tools. While there were no devices available for Grasso to easily beatmatch two songs, he had to use the traditional mixing consoles installed in the clubs, which only provided two separate line-faders to control the volume of each song. According to Rane [2012], the first DJ mixer integrating a cross-fader was designed for Grasso in 1971, enabling him to directly fade one song into another using only one fader, freeing one hand to make adjustments(see figure 1.1). The impact of Grasso's work was enormous. Cross-faders are a de facto standard in DJ'ing today. DJs have been experimenting with new kinds of devices constantly ever since, leading to new means of interaction and control. Chapter 4 "Related Work" will describe recent research projects about new DJ interfaces, interaction techniques and visualization.

The turntable

In contrast to new techniques being introduced, there is one device that has been part of DJ'ing for a long time and still is. The turntable has proven to be a one-of-a-kind device for control and musical performance. There is one

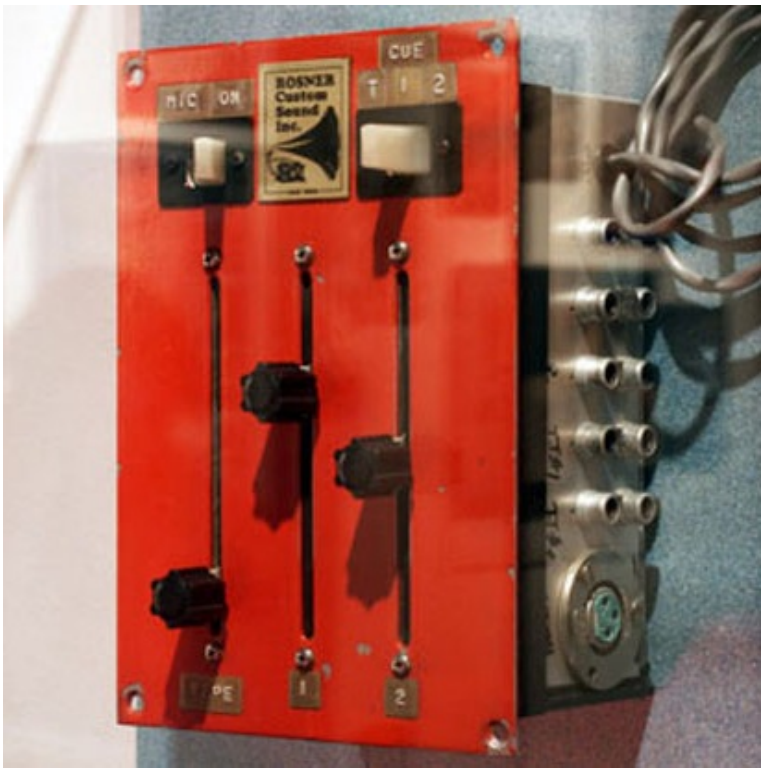


Figure 1.1: Rosie - the first DJ mixer

product that stood out the most, becoming the industry standard for turntablists and club DJs. The Technics SL 1200 has been so successful that Tom Terrell stated: *"The Technics 1200 SL direct-drive turntable is the most important musical instrument of the last two-and-a-half decades."*(Terell [98]). The SL 1200 was immensely successful, with 3.5 million units sold. *Panasonic* decided to stop production of the SL 1200 and to ultimately leave the market for analog turntables in 2010.

The turntable metaphor vs. CDJ systems

DJs have been holding on to the turntable for several reasons. The most important may be the *turntable metaphor*. CDJ systems like the *Pioneer CDJ 2000* (see figure 1.2) are trying to copy several features of vinyl based systems. By adding a jog wheel, the user is able to scratch songs in a similar way as with vinyl. Track information is displayed on a small display at the top end of the device which also enables song browsing. There are several other solutions

Figure 1.2: Pioneer - CDJ 2000

to play and manipulate music, but there is no other controller with real self-moving parts and a needle arm that allows for direct manipulation of the medium containing the music. The turntable *"metaphor is incomplete"* on other controllers. Traditional turntables provide a beautiful model by mapping the progression of music to the rotation of the vinyl (Beamish et al.). Another aspect is *in-track navigation* which is done by moving the needle arm to the actual position of music. *"The physical extent of a traditional turntable is quite suitable for human scale. Parameters, such as size, friction, weight, rate of spin (in normal operation), and motor torque, do not exceed reasonable human limits"* (Yerkes [1998]). Since this is not possible with CDJ systems, they have to rely on knobs or touch pads to scroll through songs and show song progression on displays. The CD should not be touched or

moved by the user at all, so the medium is being hidden inside the device.

Virtual setups

While vinyl DJs still had to lift their heavy vinyl cases, CDJs had the weight advantage. With the rise of digital music and MP3, a new system was introduced to the market. Virtual setups, which were completely software-based. These allowed DJing with a computer using a mouse and a keyboard. The overall acceptance for these systems was fairly low, since they did not provide DJ specific controllers. The success of these systems were uncertain. Mouse and keyboard are not meeting to the needs of DJs, because they can not provide the same hands on feel and interaction capabilities. But with the added possibilities of the computer, virtual systems were able to set themselves apart from traditional setups. One of the basic skills a DJ needs to learn is to beatmatch. To create a smooth transition between two songs, the DJ synchronizes the beats and phase of the incoming to the outgoing song. If the beats are matched, she can start to fade one song into the other, creating one continuous track. By adding the so called "*auto-sync*" feature, virtual systems were able to help people without DJ experience to make smooth transitions between songs. While this feature was very impressive for the non-DJ, a part of the DJ community was not very pleased with this kind of development (Brady [2012]).

Hybrid systems

To conquer one of the biggest weaknesses of the virtual setup - missing DJ controllers - hybrid systems were introduced. These tried to bring the strengths of the virtual and real world together by adding dedicated hardware controllers to the virtual setup, allowing for control of digital media through means well understood by DJs. By using timecode vinyls or CDs, DJs are able to control digital media with analog and digital controllers like a turntable or a CDJ system. Instead of music, they contain a timecode which is decoded by the software and used to determine the current playback position. . These systems have been such successful that even the *Disco Mix Club* (DMC), which organizes the annual *DMC World DJ Championships*, allowed one hybrid system to be used in the event.

Reimplementation and added features

This thesis concentrates on the reimplementation of the

last *DiskPlay* (Heller and Borchers [2012]) software prototype on top of a professional hybrid DJ system to bring back features that have been lost by the introduction of generic timecode vinyls. To open up additional possibilities for a hardware prototype, playback source and visualization were separated through networking. DiskPlay can be started on any other machine in the network, making it independent from the host system (playback source). For ease of use, no network configuration is needed, making it a "plug and play"-solution. In addition, further visual aids were added to output to simplify in-track navigation and provide feedback to the DJ. Finally a user test was conducted, inviting DJs to test the final system.

Acceptance

Since DiskPlay does not provide additional technical help like *"auto-sync"*, it is still unclear if such a system would be acceptable for professional DJs. There are many hardcore vinyl fans out there, who refuse to use software in their setup. Even in the hybrid system community, it is unclear how much visual and technical help is acceptable for the DJ. There are currently two companies dominating the market: *Serato* and *Native Instruments*. The divided community is reflected by *Serato's* and *Native Instruments'* approaches in their software. One - *Native Instruments* - provides a lot of features, ranging from *"auto-sync"* to *"automatic looping"*, while the other - *Serato* - does not provide technical help at all and focuses on visual output instead. An online-survey was set up to gather feedback on the acceptance issue and overall usage of technical and visual helpers. Results will be discussed in Chapter 7 "Evaluation" in addition to other findings.

1.1 Research Questions and Goals

This thesis will take a look at DiskPlay and if it has an influence on the amount of focus switches between turntable and computer screen. The new DiskPlay application is able to provide visual aids on the record, which enables the DJ to get information of a song without the need of changing her focus to a monitor. In addition to this, light is shed on the question if the DiskPlay system is acceptable to the com-

mon DJ. The thesis also contributes to the field of research by conducting a qualitative study on song synchronization with turntables to get a better understanding of how DJs complete this task. In addition, a qualitative study is conducted in which the mixing task with traditional turntables, a DVS and DiskPlay is observed.

1.2 Chapter Overview

Chapter 1: The first chapter provides an overview on DJing and the different setups that are used by professionals today. It will explain where the roots of the modern DJ are, why the turntable is still one of the most important tools and how it made its way into the digital age.

Chapter 2: Chapter 2 presents digital vinyl systems. The inner workings of a standard system is described, followed by chances that these kinds of setups provide. Afterwards problems that occur when DVS are used are discussed. Another short part investigates questions regarding in-track navigation when using turntables.

Chapter 3: Chapter 3 presents other studies comparing different DJ systems. A study is chosen where traditional turntables, a hybrid system and a touchtable are evaluated with professional DJs. Secondly, features of the old DiskPlay system are shown and which solutions could be found for several problems of a DVS.

Chapter 4: In the fourth chapter several other hardware and software prototypes are described. This includes systems that provide new channels of feedback while trying to stay true to the turntable metaphor as well as standalone hardware prototypes that try to replace the turntable as the input device.

Chapter 5: Chapter 5 will present several design decisions that have been made before implementing DiskPlay. This also involves the main DJ software on top of which the new DiskPlay is implemented. Based on problems and wishes found with the last DiskPlay system, additional features are

added. Several iterations of visual aids are presented besides ideas on how the system could support the evaluation of in-track navigation.

Chapter 6: Chapter 6 contains implementation details of the new DiskPlay system. There are several software prototypes that are presented and described. This covers the solutions of several problems that occurred when the application was implemented in addition to a performance analysis of *Serato Scratch Live*.

Chapter 7: Chapter 7 will present the design of the user study and the online survey as well as their results. A user study was conducted by inviting professional DJs to test DiskPlay in a controlled environment, allowing them to mix preselected songs. The online survey has been made public in several DJ-forums.

Chapter 8: Finally, chapter 8 will summarize the work of this thesis and its contribution to the research on this topic. It will give a final overview of the findings and provide possibilities for future work on DiskPlay.

Chapter 2

Digital Vinyl Systems

Digital Vinyl Systems(DVS - see figure 2.1) have been around for quite some time. With the introduction of *Final Scratch* by *N2IT* in corporation with *Stanton Magnetics* in 2001, there has been much controversy surrounding digitally enhanced DJ equipment. While there are many DJs refusing to use anything besides the standard analog turntable and traditional vinyl, many new devices for controlling digital media have been introduced and vanished. Few of these systems have ultimately found a permanent place in the DJ landscape.

The turntable is used as a controller for digital media

The integration of the turntable as a controller provided an alternative for all DJs that wanted to manipulate digital songs with a tool they are familiar with. To make this possible, a timecode vinyl is used. The analog signal of the turntable is sent to an audio interface, which supplies the laptop with a digital signal. The software running on the computer receives the information from the AD-converter and changes speed and position of the current track accordingly.

other advantages of a DVS and the downside to traditional vinyl

Many different setups and combinations can be used today. The DJ is able to use up to four controllers with a DVS, mixing CDJ devices with turntables, opening up even more possibilities to mix and perform. Finding songs in a digital library with just a few button clicks is another big bonus. Several different online vendors make it extremely easy to

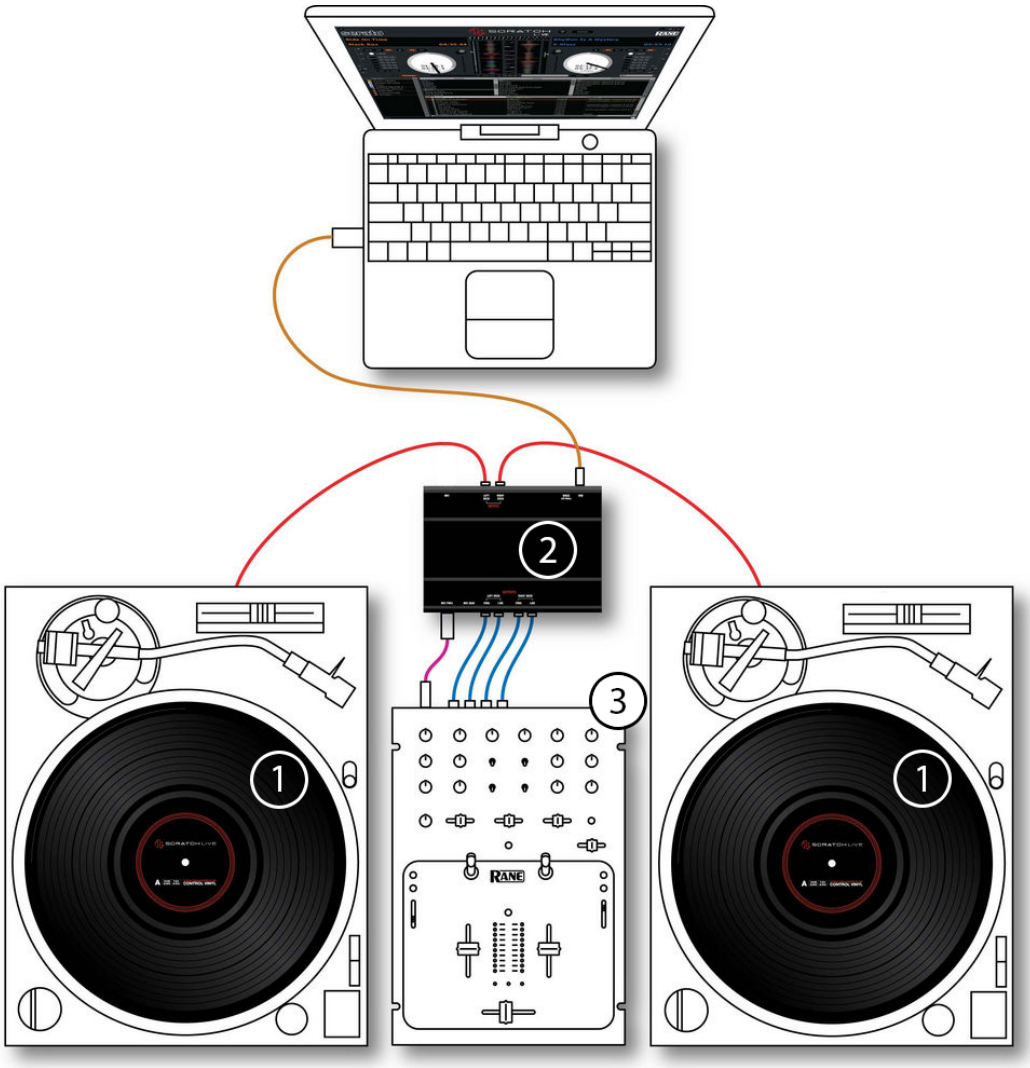


Figure 2.1: Typical DVS setup - 1: Turntables with timecode vinyl — 2: AD-converter — 3: DJ mixer - source: Serato.com

get your hands on the newest tracks which will be impossible to find on vinyl. There are less and less record stores around and ordering online will leave the buyer unclear of the actual quality of the recording. In addition to this, there is a 70% difference in price when between vinyl and MP3. . Furthermore, there are no shipping costs when ordering digital copies. This is even more of a problem if the DJ is actually a producer and wants to play his own tracks. Pressing vinyl records is rather complicated and expensive.

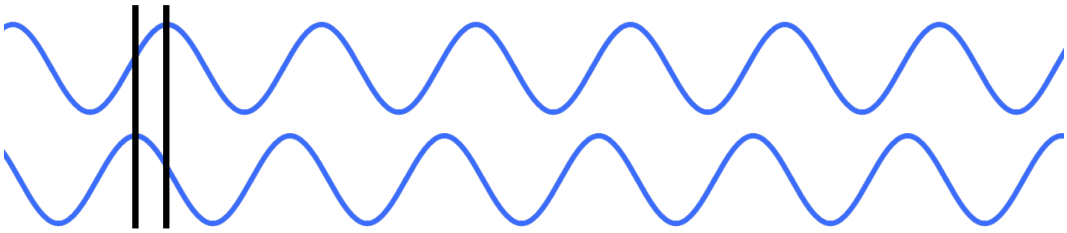


Figure 2.2: Delay of sinewave to determine direction of rotation

Disc jockeys can be video jockeys as well

The computer itself opens up new ways to present media. Additional video jockey software provides further possibilities to enhance the DJs performance. Even top level turntablists converted to VJing (Golden [2008]). Special plugins and third party software allows the DJ to improve on her performance with movies and effects, that are reacting to the music.

Timecode Vinyl

The speed of the vinyl is measured by tracking two sine waves - one for every stereo channel. If the record spins at normal speed, a 1 kHz (*Serato* uses 1 kHz - *Native Instruments* uses 2 kHz) sine wave is put out by the turntable. Slowing the vinyl down will lead to lower-, speeding it up to higher frequency. As mentioned before, there are two channels containing sine waves to enable the software to track playback direction. By delaying one of the two sine waves for a short period of time (see figure 2.2), there is always one channel peaking before the other. Tracking the needle position requires a unique identifier for every position on the record, therefore timestamps are embedded into the analog signal. Serato's timecode vinyl uses a binary code which is additionally phase-shifted between from one channel to the other. The binary code does not only provide low and high peaks, but low-low, low-high, high-high and high-low peaks. Serato as well as Native Instruments do not publish how they decode the signal.

2.1 Problems of Digital Vinyl Systems

Traditional vinyl provided information

Eliminating the traditional vinyl did not only bring advantages. There are several feature a DVS just cannot provide.

Every vinyl record has its own "fingerprint" - the record grooves containing the music, visual to the naked eye. The mood of the song determines how these grooves look like. If there are loud passages, the grooves need to be far apart. If the passage is rather soft, they do not need as much space (Schlager [1994]). This enabled the DJ to see the mood of the song on the record itself, making it an irreplaceable tool for in-track navigation. Additionally there are visual cues for song beginning and end. The grooves are packed tightly together and form borders around songs. By using only one generic record for all songs, these features are lost, forcing the user to look at the screen to get information.

Using one record for all songs means that there is no possibility to add cuepoints directly to the record. On traditional vinyl round stickers were used to mark special samples or positions in a song, removing the need to search for them. The tone arm was dropped just before the sticker, which guided the needle into correct groove. There is a software solution for this problem, allowing for digital cuepoints. By preparing songs beforehand, the user can mark important spots he will need later on. But if the software is used in absolute mode, meaning the absolute position of the needle on the record is tracked, the user cannot jump directly to the passage, but has to navigate using computer screen and turntable.

Mouse and keyboard as input device

Most DVS software offer an intuitive music library management system. Whenever a track is ending, a new track has to be loaded into the deck. This is most commonly done via a mouse or touchpad. The DJ has to move to other input devices to make this happen. In a standard setup, a laptop is used for the job, which is then positioned above or beside the turntables. But DJs seem to avoid the computer as a controller as much as possible.

Due to the fact that there is only one point of contact to manipulate the program, it is not always the best option to use the mouse or keyboard. One of the most important aspects during performance seems to be parallel interaction (Hook et al. [2011]), which mouse and keyboard cannot provide. Whenever the mouse is moved to another button, the mode of the input device changes, making it impractical for eyes-

free use. The ability to do several things at once make external physical controllers an essential tool for the performing DJ.

As a result a whole industry is producing external controllers, letting users manipulate every aspect of the software without the need to switch to mouse or keyboard. Loading tracks into decks is done via knobs and dials directly next to the turntable. MIDI controllers present new ways of consistent control mapping. While the mouse has to be grabbed, aimed at the target button and then clicked, a dedicated knob or button on a special purpose controller just needs to be pressed by the user to perform a certain action.

Appealing performance of a DJ is important

Using the computer as a source of information and for changing tracks leads to a different problem. The DJ seems to be disconnected from the crowd and his performance, staring at his screen and using the mouse. According to one DJ in (Brady [2012]), the crowd *"will judge the DJ on the visual aspect as well"*. This is not surprising since most DJs consider themselves performers and people are willing to pay to see the artist "perform". The DJ also suggest that *"playing vinyl on turntables was much more visually appealing than other methods"* and also added that if the *"DJ could impress the crowd visually on top of the music being played, even more respect should be given to the DJ"*. While this is only one opinion on the matter, it may indicate another problem of a standard DVS setup.

The introduction of DVS lead to a phenomenon also called *Serato Face*: *"Serato Face, noun: a blank or inappropriate facial expression worn while staring at a screen at a dance party or club"*[1]. *DJ TECHTOOLS*[2] dedicated a whole article on how to avoid *Serato Face*. In (Heller and Borchers [2012]) one DJ states: *"I often look to the display, no matter if I want to gain information from it or not. It's a habit"*. It seems that there are many DJs having the same problem. With the computer screen as the only source of information, the DJ has to depend on it every time he cannot get the information

[1] http://seratoface.tumblr.com/

[2] http://www.djtechtools.com/2013/02/04/how-to-avoid-serato-face-solving-dj-screen-gazing/

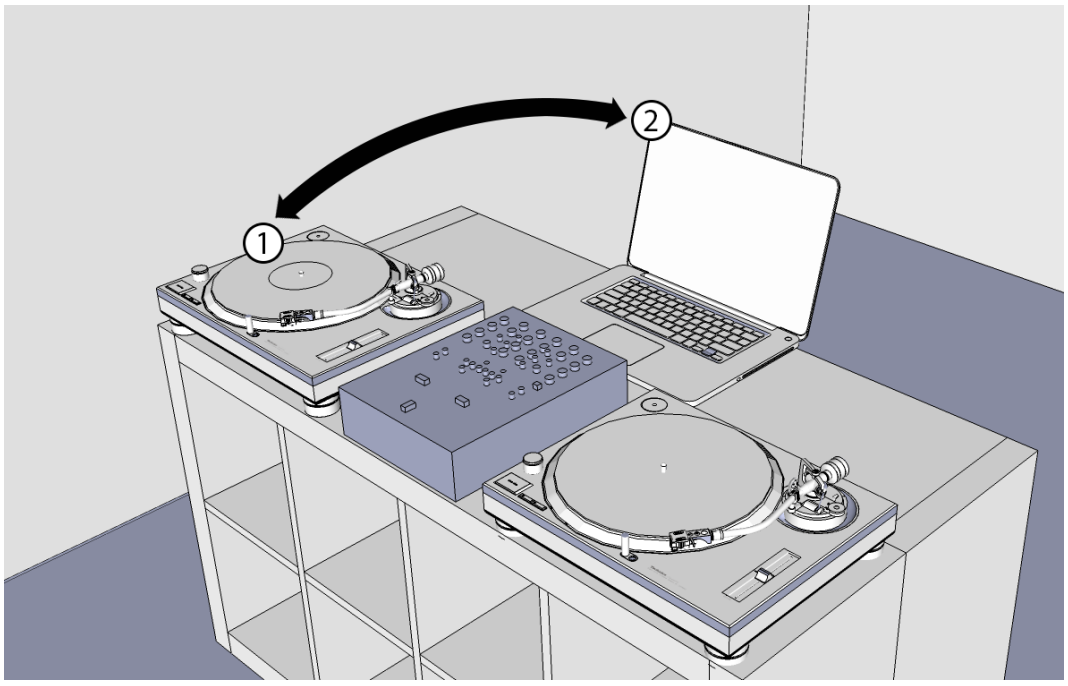


Figure 2.3: Focus switching between turntable (1 - providing control) and computer screen (2 - providing information)

just by hearing. People want to connect to the performer but it seems increasingly more difficult if the DJ creates the impression that he is working with his laptop. This may suggests that spectators do not consider the computer as a performance device but rather a tool for daily work or just for loading tracks.

Focus switches lead to problems

The turntable offers direct manipulation of the record, providing excellent control and information. But by using the timecode-vinyl, information and control are being separated (see figure 2.3). This leads to several problems. Since there is no eyes-free use of the turntable when navigating, several focus switches between turntable and computer screen are required to complete the task successfully.

Consider the task of searching for a specific position in a track. The timecode-vinyl does not provide any visual information on it's own, which leaves the DJ to either use the audio channel or the display to find the current track's position. To find a specific spot, the DJ changes focus to

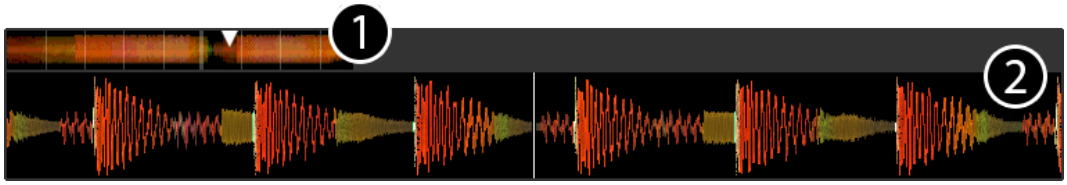


Figure 2.4: Serato Waveform Display - 1: Song overview — 2: Local waveform

the turntable, picks up the needle arm, drops it on certain position on the record. A focus switch to the software is required to check his current location inside the track. If the outcome is not good enough, another focus is needed to pick up the needle again and make a correction.

Since the audio channel is ephemeral and does only provide a snapshot of the current position, it lacks the ability to provide an overview of the song. Arons [1997] states that "*skimming or browsing audio recordings is much more difficult than visually scanning a document because of the temporal nature of audio*". Using the information on the display, the DJ cannot only see where his current location in the track is, but also how the overall song is structured. This is often visualized by a (multilevel) waveform display. In case of *Serato Scratch Live*, there is a multilevel waveform in place (see figure 2.4). It provides a high level overview of the song structure. Since the vinyl can no longer support the DJ with information by looking at the grooves, the overview waveform can compensate for the missing information. Additionally a moving a waveform is used to offer local information, making it more comfortable to find a certain beat or drop visually.

By adding visual helpers, software can overcome some of its limitations regarding traditional vinyl. But the focus switches put an extra load on the working memory of the DJ. Considering that beatmatching alone is a complex task, it should be crucial to reduce any extra pressure on the user. The DJ has to listen at two songs simultaneously, using headphones on one ear and synchronize the phase and tempo of the two tracks. Meanwhile she always has to keep an eye out for remaining tracklength of the outgoing song. Beamish et al. [2004] states that "*Many DJs require the entire duration of the outgoing song to synchronize the incoming song*",

which suggests that time is of the essence when it comes to beatmatching. With every extra focus switch the user loses time, she could have used to perform.

Chapter 3

Comparative Turntable Studies

Before going into detail of design ideas, it is important to take a look at other comparative studies conducted on turntables. Some of the research concentrates on new interfaces to enable new ways of performing for DJs and comparing these interfaces to a traditional setup.

This chapter will present two studies comparing traditional, hybrid and virtual systems regarding their performance when mixing songs. At first, an extensive study of a multitouch tabletop application is evaluated with DJs against standard turntables and a hybrid system. It will show the importance of haptic feedback especially for scratch DJs and highlight the importance of visual feedback.

After this, the earlier DiskPlay project is presented. It was focused on enhancing in-track navigation with digital vinyl systems due to the lack of features of timecode vinyls. A series of solutions for different problems with DVS are shown. Additionally the system was evaluated with professional DJs.

Figure 3.1: A virtual multitouch DJ Setup

3.1 Battle of the DJs

A virtual multitouch DJ setup

Lopes et al. present a study on modern and traditional DJ setups. The study shows a new approach to DJing by presenting a touchable tabletop user interface(see figure 3.1) resembling a traditional DJ setup. The prototype features a multitouch surface, allowing the DJ to work with both hands in parallel.

Classification

Before the prototype is shown, the authors classify DJ systems according to their interaction and technical capabilities. There are basically 3 types of DJ setups plus the new multitouch setup:

- Traditional vinyl setups (**T**)
- Virtual setups (**V**)
- Hybrid setups (**H**)
- Multitouch setups (**Mt**)

The interface resembles the traditional DJ setup

Figure 3.2 shows the prototype's user interface. It was built around the *"user's mental model"*. This includes *"sound*

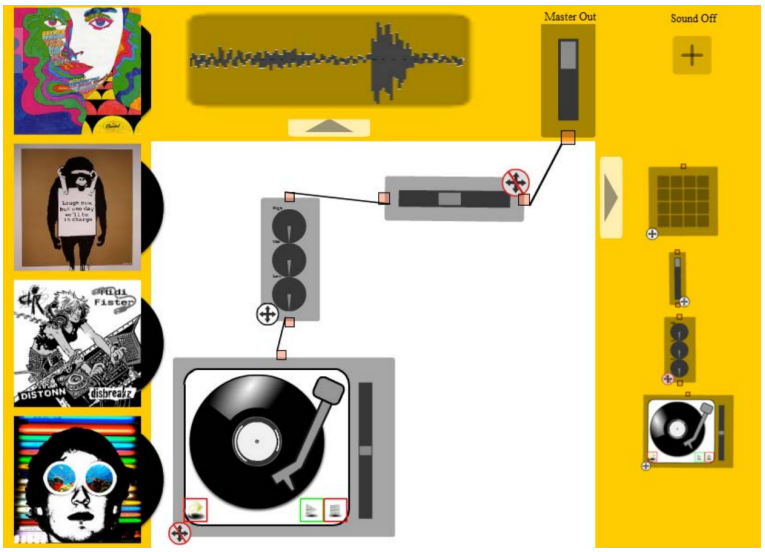


Figure 3.2: Prototype touchtable user interface

sources, records, audio manipulators (volume-faders, equalizer knobs, cross-faders, and so forth)". By using objects familiar to the DJ, learning time is shortened and the widgets do not need any further explanation. Additionally, touchtables provide the same horizontal setup DJs are accustomed to, making it more natural than computer screens and WIMP interfaces. Furthermore, the prototype supports the *traditional gesture lexicon* of scratch DJs. The implemented turntable widgets react to touch in a similar way a real turntable does. DJs are able to slow down the record by touching it in the label as well as speeding it up by pushing the record into playback direction.

3.1.1 Study

10 Study participants including scratch- and mix-DJs

The actual study was conducted with 10 experts, dividing them into 2 classes: *Radio/Club DJs* and *Scratch DJs*. The Radio/Club DJ concentrates on creating smooth transitions between songs, while the Scratch DJ tries to create new music by playing samples from one record. By this, Scratch DJs can create new sounds, using one song as a basic background song and the other track to mix in samples. There

is a big difference in skill between a common Club/Radio DJ and a Scratch DJ. While beatmatching is seen as a basic skill that has to be learned to be called a DJ (Brady [2012]), scratching is considered an advanced technique promoting a DJ to a music maker rather than music player.

Study setup

Mixxx(Andersen [2003a]) was used as the host program for music playback, testing **V**, **H** and **Mt**. It was especially selected because none of the DJs has ever worked with Mixxx, therefore none of the participants would be biased.

3 phase study

The user test was conducted in three phases. First the DJs were introduced to Mixxx and to the multitouch prototype. This was necessary since none of the DJs had worked with Mixxx or the prototype before. After the tutorial, DJs had to complete several beatmixing tasks. Two songs were randomly chosen from the song pool, which had to be beatmatched and mixed with a specific setup. The participants had to announce when the task was complete and the time was clocked. By this, the authors were able to compare task completion time for beatmatching on all of the four different setups. In the last phase, DJs were able to freely perform with the multitouch setup and the songs of their choice. The authors wanted to give the user some extra time to experience the new system on its own. In a final interview, the opinions and thoughts of the participants could be recorded.

3.1.2 Results

Virtual setups fall behind

The results of the study show how important the input device for the DJ actually is. There are big differences regarding task completion time with every test-setup (see figure 3.3). Since the virtual setups have been criticized very often for the missing DJ input devices, it shows the worst performance. Mouse and keyboard seem to be sufficient for this task, but the results suggest that they are very inefficient. In average, DJs needed 100 seconds longer to complete the beatmatching task than with the third best setup. Considering that the average mixing time with **V** exceeds the four minute mark, virtual systems seem to be unfit for

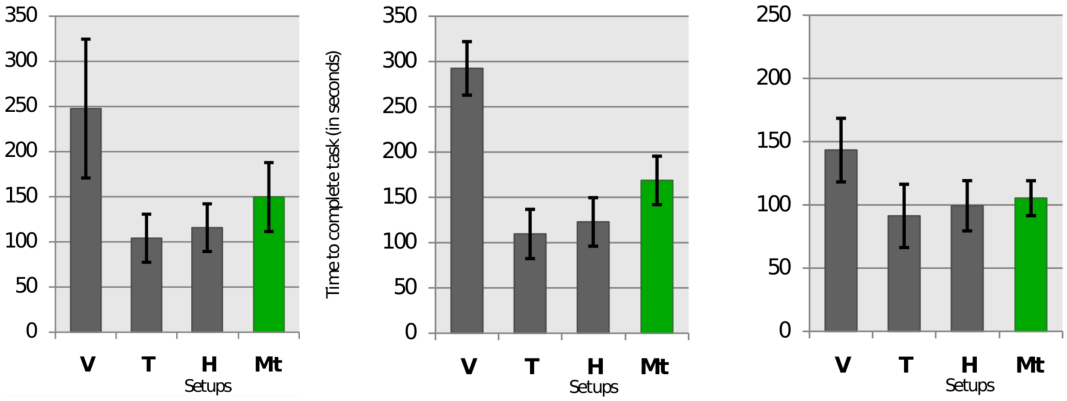


Figure 3.3: Comparison between the different setups when beatmatching - Average task completion time with each setup (**left**), task completion time for Radio/Club DJs (**middle**) and task completion time for Scratch DJs (**right**)

a live DJ performance, since they do not leave much time for DJs to do anything else besides matching the beat and create a smooth transition.

Multitouch can help virtual setups

Although the proposed multitouch solution is purely virtual as well, the results show that it outperforms **V** with regard to task completion time. Scratch DJs nearly reached the level of **H** and **T**. The authors conclude that the increased performance of the **Mt**-setup can be explained by *"touch support, bimanual and horizontal interaction help"*.

The turntable metaphor stays incomplete

H and **T** provide the best performance in this user test. Although the authors tried to implement as many features of turntables as possible, the multitouch setup is missing a critical component. There is no real record or turntable that can be touched or manipulated. The authors conclude: *"The haptic feedback provided by touch surfaces is not good enough for Scratch DJs"*. **H** and **T** still outperform **Mt** by 30 to 40 seconds.

3.2 DiskPlay

Another direction

Lopes et al. showed that virtual setups could be enhanced by adding multitouch and widgets resembling traditional components. When Heller and Borchers [2012] and Lauten

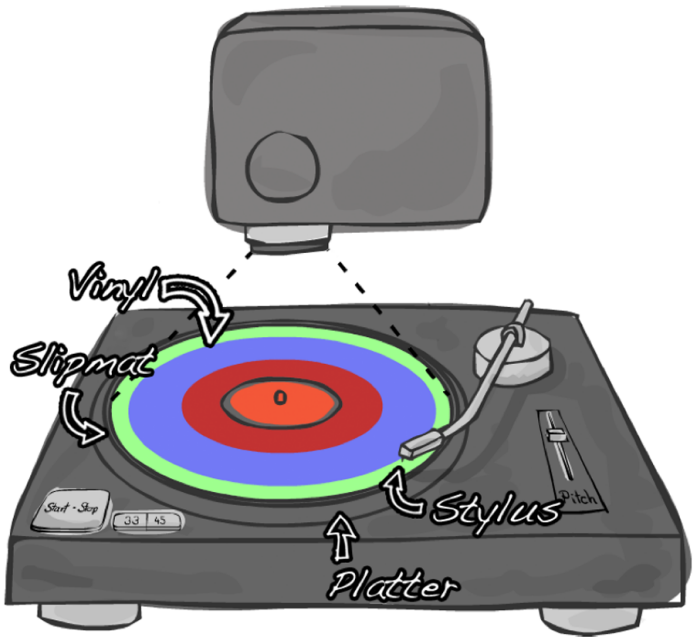


Figure 3.4: DiskPlay concept

[2011] presented *DiskPlay*, they went in a different direction. Instead of enhancing the virtual setup with widgets from the traditional DJ domain, they enhanced the traditional DJ setup with features of virtual systems.

Bring back what was lost

DiskPlay was designed to enhance in-track navigation with digital vinyl systems. The authors recognized the drawbacks of timecode vinyl and tried to bring back several features of the traditional record. Since a generic vinyl can not provide specific information about a song, DJs have to look back and forth between turntable and computer screen. With DiskPlay the authors present a unique system that provides visual clues to the DJ, making her mostly independent from the computer screen.

Overview

DiskPlay describes several features that are added via a projector mounted on top of the turntable (see figure 3.4). Additionally, a study was conducted by Lauten [2011] to

evaluate the benefits of the final system compared to a standard DVS or turntable setup when navigating in a track. The prototype was implemented on top of *Mixxx* (Andersen [2003b]), which provides an open API, flexible configuration and is free of charge.

3.2.1 Features

Gathering information

Before starting off with the software design, the authors needed to find out what DJs would actually expect from a visually enhanced DVS. To gain insight on the issue, videos of DJs performing live were evaluated. Additionally, they paid a visit to a *Serato* showcase with a professional DJ. This led to the following design goals: Add a song visualization and give DJs a representation of cuepoints on the record.

Visualizing the song

To bring back features of traditional vinyl, the traditional record has to be examined. The physical grooves that are part of every vinyl provided additional information on the songs. Loud passages are fairly bright, while soft passages can be spotted by looking for darker segments. This also enables the DJ to see song start and end. They are indicated by black circles, since they only contain silence. One DJ stated that "*the most embarrassing thing that can happen to a DJ is that the song is over without him noticing it and therefore has no time to create a smooth transition by beatmatching*". A standard DVS can only provide information on the computer screen. DiskPlay adds this feature directly to the record(see figure 3.5), so the remaining track length can be checked without having to change focus to the computer screen.

Finding the mark

Because a DVS uses only one generic record for playback, adding cuepoints by pasting stickers on the vinyl is difficult. The DJ would need more than one timecode vinyl, which would lead to carrying heavy crates again. DiskPlay tackles this problem by adding a visual representation of stickers to the projection. Cuepoints can be set up in software and are then represented as small circles at the corresponding position. The turntable metaphor dictates that the cuepoints should rotate with the record. While this creates the illusion that the cuepoints stick to the vinyl, often

Figure 3.5: DiskPlay feature overview: (a) tracklength on the vinyl - (b) played part of the track - (c) unused part of vinyl - (d) cuepoint

they are not in the proximity of the needle. The record has to be rotated to move the marker into proximity of the stylus. This issue was resolved by adding one black circle following the grooves for every cuepoint . The *orbit* allows for an easy needle drop without having to move the cuepoint to the right position first. In addition, the needle is always able to traverse a virtual cuepoint while real stickers would push it into a certain groove.

3.2.2 Study

Four professional participants for a user study

To evaluate DiskPlay, another user test was conducted. Four professional DJs were invited to take part in an observational study. Having worked with digital vinyl systems for at least half a year, none of the participants were new to this kind of setup. With five to 20 years of experience, the DJs can be considered skilled users. An initial survey was filled out by candidates to get some insight on their experience and preferences regarding digital vinyl systems and DJing in general.

Hardware setup

The hardware system depicted in figure 3.4 was set up for the study. Two Technics SL-1200 MK5 and a standard DJ Mixer (Gemini BPM-1000) integrating a BPM-meter were used. Only one of the turntables was augmented using DiskPlay.

Study setup - qualitative

A qualitative study was set up to take a general look at the DJs behavior when using DiskPlay. At first, Mixxx was presented to the participants. Because none of the DJs had used Mixxx before, a 25 minute accommodation phase was introduced to familiarize the candidates to the user interface. In the second phase, DiskPlay was enabled. The DJs had 30 minutes to work with the system, mixing several songs of their choice. Rather than asking questions, the authors silently observed the participant.

Study setup - quantitative

To get results on DiskPlay's performance with in-track navigation, a quantitative study was put together. A search task was evaluated where the candidates had to find a certain spot in a song using just their hearing, a digital vinyl system and DiskPlay. The time was clocked to compare the different systems. Songs were picked by the DJs which had to mark a certain spot inside the track. The needle arm was put in its resting position before the DJs were allowed to start. The participants had to find the cuepoint as fast as possible.

3.2.3 Results

Study results - quantitative

The qualitative study shows that DiskPlay enabled the participants to find their target considerably faster than just by hearing (see figure 3.6). This is not surprising, considering that sound does not provide an overview of a song. Lauten [2011] concludes that a "*visual representation is essential for navigating quickly through a track*". When comparing DiskPlay and the Mixxx interface, there is only a small difference in performance. While Mixxx outperforms DiskPlay just by a small amount, the number of samples that were taken may not be representative.

Study results - qualitative

While DiskPlay was turned off, the participants used

User	*Mixxx*	*DiskPlay*	*bhearing*
1	11 sec	5 sec	25 sec
	8 sec	3 sec	12 sec
	11 sec	8 sec	15 sec
2	8 sec	3 sec	24 sec
	9 sec	7 sec	12 sec
	11 sec	31 sec	15 sec
3	24 sec	28 sec	42 sec
	9 sec	18 sec	9 sec
	5 sec	8 sec	9 sec
4	14 sec	5 sec	21 sec
	10 sec	24 sec	25 sec
	12 sec	20 sec	22 sec

Figure 3.6: DiskPlay search task results

the computer display to orientate themselves in the song. When DiskPlay was turned on, one DJ used the computer screen only to load new tracks into the decks. The participant used either DiskPlay or his hearing to navigate or get information. Another DJ started off using the cuepoint feature to help him navigate a track. Unfortunately he stopped using them after a while because he *"could not hit the exact groove of the cue point and did not know if he had to spin the record one, two, or three times to reach the cue-point"*. A third DJ exhibited a behavior similar to the phenomenon described in section 2.1 "Problems of Digital Vinyl Systems" - *Serato Face*. He often looked at the computer screen whether DiskPlay was enabled or turned off. The DJ stated: *""I often look to the display, no matter if I want to gain information from it or not. It's a habit"*.

Study results - additional feedback

In a final interview, DJs were able to state their opinion on the system and provide feedback. The participants liked

the track visualization, but asked for a waveform, a time- and BPM display. To get the attention of the DJ when tracks are dangerously close to the end, one DJ suggested to add a flashing animation.

Chapter 4

Related Work

DJs are always on the lookout for new ways to improve themselves. There are several other projects trying to bring new devices to the DJ domain. Some of this work is trying to replace the turntable as an input device while others try to visualize important information in new ways. What they have in common is the wish to introduce new means of making music and maybe make the life of the DJ a little bit easier.

This chapter will describe several other projects researching new interaction techniques and devices for DJs. It will start off with a presentation of *two turntables and a mobile phone* (Bryan and Wang [2011]) which describes a hardware prototype that allows DJs to use their smartphones as an input device.

4.1 Two Turntables and a Mobile Phone

Two turntables and a mobile phone introduce a software/hardware prototype (see figure 4.1) which combines smartphones, turntables and a computer to present an alternative to current digital vinyl systems.

Digital vinyl system have been very popular, but they have

Replacing the record because it has drawbacks

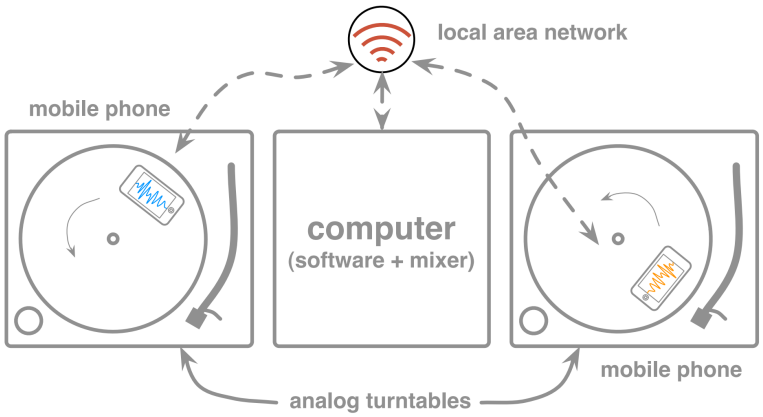


Figure 4.1: 2 turntables and a mobile phone: system overview

several disadvantages. The authors criticize that timecode vinyl wears out over time, have a length limitation, as well as possible needle jumps during a performance. Turntables rely on the tonearm to be positioned on the record, but it can obstruct the DJ. While the turntable is also being praised for his "*simple physical control and inherent proprioceptive feedback*" which allows for the "*possibility of incredible virtuosity and skill without hindering a beginner's zeal*", the authors suggest replacing the record with a mobile phone.

The smartphone as a motion sensor

The mobile phone is attached to a modified record. Most smartphones today are equipped with an accelerometer/gyroscope to sense motion. The authors use the data to calculate the rotational motion of the smartphone on the turntable. A WLAN connection is used to transmit the raw data to the computer which will determine rotational velocity and the distance the smartphone has traveled to change the song's position and tempo accordingly. Although a smooth rotational tracking is not a trivial task, the authors state that "*the system can achieve a precise and robust measurement of instantaneous rotational velocity*". The system is able to deal with extreme changes when it is being rotated, which suggests that it could be suitable even for scratching.

Provide visual feedback where it belongs

By using the screen of the phone, the DJ is able get visual feedback in the same place where she is controlling the music. The authors propose a visualization of the songs wave-

form on the phone to provide DJs with an additional visual cue. Furthermore, dots or tape could be presented on the display, marking cue points or samples.

Additional input device

Since the mobile phone is not only a rotational input device for the turntable, it is also a direct input device for the user. The touchscreen could be used to zoom in and out of the waveform, change settings or select new songs. Hereby, the DJ could eliminate the computer screen, performing only with his turntables and phones.

Untethered scratching

Although the smartphone is attached to the the record, it can possibly be removed. As a result the input device is not necessarily bound to the turntable. The DJ can use the phone to do *untethered scratching*, controlling the music with it in mid-air. It opens a new way of interacting with the audience and move around.

Two turntables and a mobile phone presents an interesting way to enhance DJ interaction while still holding on to the turnable metaphor. The presented system shows how a display can be integrated into a turntable, providing feedback and control to the DJ. Furthermore, the ability to use the smartphone's touchscreen as an input device could ultimately remove the computer screen from a DVS setup, since tracks could be loaded using the smartphone instead.

4.2 The DJammer

The DJammer (Slayden et al. [2005]) is a musical input device allowing DJs to scratch in mid air using a small input device (see figure 4.1) they can fit in the palm of their hand. It features real time manipulation of music and control capabilities by offering three additional buttons.

Two important questions

The authors try to answer the following two questions:

- *"How does mobility change the experience for the DJ and the audience?"*

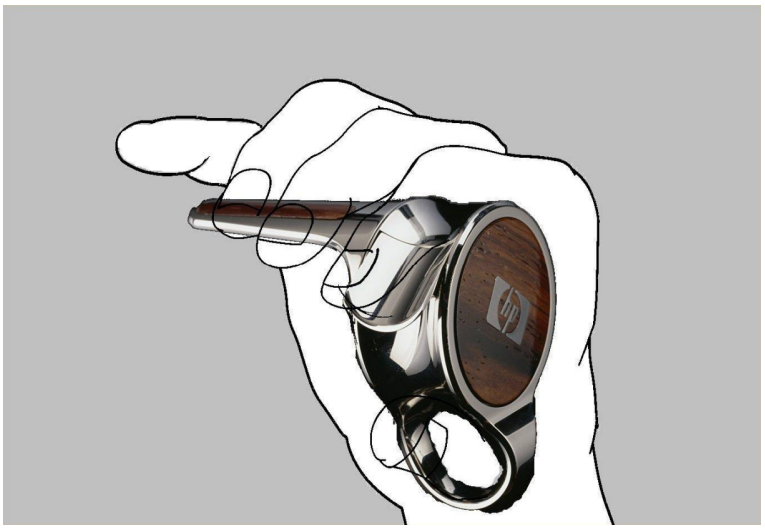


Figure 4.2: 3-button DJammer prototype

- *"What types of control over the music would they need and what actions would they want to perform using a mobile device*?"

Prototype design

There were two prototypes of the DJammer. The first device consisted of a 3D-motion sensor, an optical sensor, a wireless connector and a headphone output. Scratching could be done by shaking the whole device or moving a finger over the optical sensor. The headphone output enabled the DJ to listen to the music wherever she took the DJammer. A wireless connection decoupled the device from any cables. Because the first prototype did not provide the necessary accuracy of control, a second prototype was built (see figure 4.1). The authors realized that the turntable metaphor was important. They state that the new device creates *"a usage model similar to that of a turntable"*. Additionally, there were new sensors installed which provided greater precision. For control, the authors decided to add three buttons to the prototype.

Reference button mapping

A professional DJ was consulted to map the buttons of the DJammer. Since DJs love to customize their equipment, it was important to the authors to keep the DJammer flexible. For this reason, the functions of the buttons are freely ed-

itable. To give the user a reference mapping, the scratch DJ suggested to link the following functions to the DJammer: *Enable or disable scratching* to allow the DJ to move freely without performing scratch gestures. Another button was mapped to *mute*, blocking the song's audio output on the speakers. By this the DJ can browse the song and find certain beats. The last button should be mapped to *jump to a breakpoint* (or cuepoint) so the DJ can jump to a sample marked beforehand.

Evaluation with six professional DJs

Evaluation was done with six professional DJs. The DJammer was demonstrated to the participants, especially the scratching feature. In a free play session, the DJs were able to test the device and state their opinion. Although the authors tried to resemble the feel of vinyl scratching, the DJs stated that the "*experience of air-scratching is different from that of scratching vinyl*". The overall size and weight of the device was perceived very positive.

Surprisingly, the mobility that the DJammer provided was received controversial. While some of the DJs liked the idea of being able to walk around and perform for the audience, other DJs did not want to leave their other equipment. One DJ statet that "*It's counterintuitive... The DJ thing is behind the booth.*". All DJs noted that they would like the DJammer to be even more customizable allowing them to map custom controls, that the authors did not think of, to buttons .

Summary: an excellent additional wireless controller

In conclusion, the DJammer is a controversial project. It allows the DJ to move around freely and work with his audience. But not all DJs were eager to leave their booth. The authors gained insight on what actions should be mapped to an input device that can be used to scratch in mid-air. Although mobility was not an issue for all DJs, the idea of having an additional wireless controller seems to be an excellent concept.

4.3 BeatJockey

With BeatJockey, Molina et al. present a software solution for DJs that is able to "*suggest song slices*" from other songs

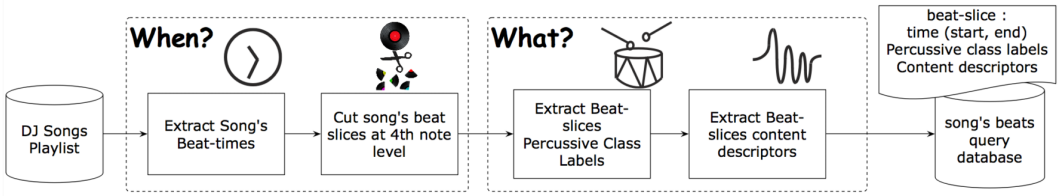


Figure 4.3: Basic BeatJockey workflow

to mix into the current track. Figure 4.3 illustrates the basic workflow of the BeatJockey: The DJ's song playlist is analyzed, the song's beats are extracted and the track is cut at the 4th note level. These snippets are classified and grouped by the application according to the included percussion. Finally, BeatJockey places the information in a database, so they can be queried when needed. The system was built on top of the Reactable, *"a musical tangible user interface"*.

Four questions for the mixing-DJ - WHAT

At first, the authors identify four main questions of a mixing-DJ: A performing DJ needs to know *what* beat slices she could play next. They should be taken from a song that is easy to mix into the last song. To help with this decision, BeatJockey uses content descriptors and machine learning to highlight matching slices for the DJ. The content descriptors classify songs and slices according to drumsounds and grouping them corresponding to spectral energy, flatness and other criteria. Classification is done by a support vector machine, labeling every snippet to *"reflect which elements of a drum kit are more likely to be present in the beat"*.

Four questions for the mixing-DJ - WHEN

If the DJ has decided on the next slice, she needs to know *when* to start fading it in. BeatJockey uses BeatRoot, an algorithm that is able to extract the beat of a song. To help the DJ to play the slice at the correct time, they are matched to the beat (BPM) of the master song and played at the correct time.

Four questions for the mixing-DJ - WHICH

When the beat is matched and the DJ is ready to mix, she needs to know *which* parts of the song should be introduced. To decide which slice to suggest, BeatJockey tries to maintain the percussive structure of the master songs current slice. The database is queried for a snipped that

features the same characteristics as the current one. When there is no slice available that would fit the master song, no slice is being suggested.

Four questions for the mixing-DJ - HOW

In the end, every DJ needs to know *how* to beatmatch songs to be able to create a smooth transition. BeatJockey uses the Reactable, which on the one hand provides only a limited DJ interface, but allows for multiple users to work in parallel on the device. The authors created two new objects for the Reactable: A new *BeatJockey DJ Player*-object which represents the master song. The user can select the master song and change its gain by turning the object. Secondly, the *BeatJockey Control*-object is introduced. This new item can be connected to the DJ Player-object to link it to the master song. The Control-object will then start to suggest beat slices for the linked master which can be chosen and played by clicking on them with a finger. Rotating the object will change the gain of the sound slices.

Evaluation

The authors did not include a user test to evaluate the system with professional or amateur DJs. But they asked ten participants to listen to prerecorded sessions with the BeatJockey. Results showed that the listeners preferred the suggested beat slices over randomly chosen slices from the database.

Conclusion

The presented system should be able to help amateur DJs to play different samples in their songs without prior knowledge of beatmatching or experience with song synchronization. Expert DJs could benefit from BeatJockey as an additional performance tool. The authors brought up four important questions when it comes to DJing and tried to find an answer for all of them. Without a detailed evaluation with professional and amateur users, it is hard to say if DJs would actually like to use such a system.

4.4 D'GROOVE

The D'Groove (Beamish et al. [2004]) is a new kind of haptic turntable. It enables the playback of digital media while preserving parts of the turntable metaphor. Haptic feed-

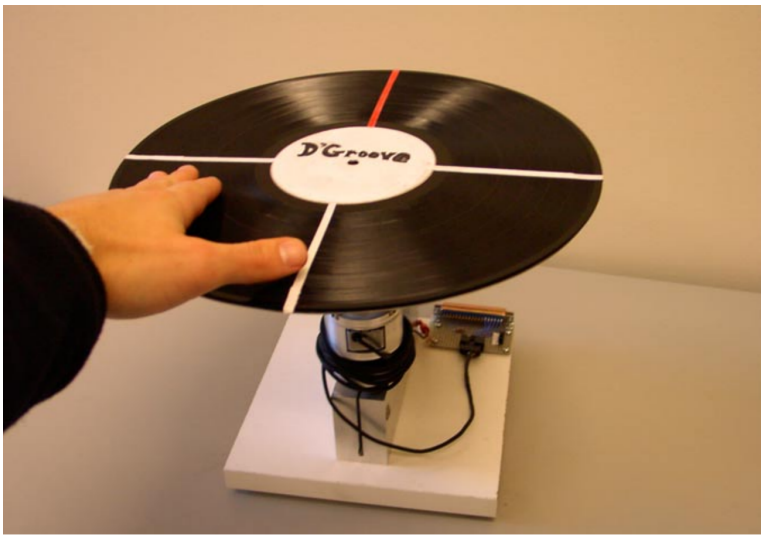


Figure 4.4: The D'Groove turntable

back is expanded to the auditory domain, to help the DJ to feel the music.

Prototype design - the disassembled turntable

The whole system consists of three input devices: The turntable platter, the Q-Slider and a pitch slider. These input devices are connected to a JASS audio synthesis engine (van den Doel and Pai [2001]). Since the turntable is also an output device, the computer controls the motor of the turntable to provide feedback to the user. The authors tried to reduce the latency of the system to a minimum, reaching less than ten ms. In addition they state that their approach "*is consequently able to maintain and extend the traditional turntable's visual, auditory and haptic communication with the user*".

The turntable without the needle arm

The turntable platter (see figure 4.4) is made out of a real vinyl on top of a 90 watt motor. The turntable's rotational position is read from a high resolution encoder providing 14400 readings per cycle. By using a motor, the vinyl can spin on its own, representing the progression of music. Because the motor is controlled by the computer, the authors realized that they could enhance the rotating vinyl with additional visual feedback. Four lines were added to the record. Instead of letting the vinyl spin with the

same velocity for every song, therefore representing playback speed, they chose to let it spin according to its beats. Every line represents an occurring beat, with the red line as a phase indicator.

Visual beat tracking

The visual representation of beats on the record can help to reduce the auditory load of the DJ. Using two turntables, it would be possible to check the alignment of phase by comparing the red line's position and the change in BPM by checking the difference in rotational velocity.

Four additional haptic modes for the DJ

The ability to control the turntable's motor with the computer opens up new performance capabilities and possibilities to provide haptic feedback. Four modes, providing different kinds of haptic feedback, were implemented by the authors.

Spring-mode

In *spring*-mode, the turntable sticks to a certain point. When the record is rotated, it exercises force to return to its point of origin, as if a spring was attached to it.

Bumps for beats

Bumps for beats creates a virtual bump for every beat that is traversed by the record. This allows for an eyes-free use of the turntable to find beats by feeling them. The authors also add that it could "*help with navigation through a song, and could also provide periodic hills of force to scratch against*".

Resitance-mode

Resistance-mode maps the songs current mood to the rotational resistance of the record. Loud passages lead to a stronger force on the motor, while damped or moodier parts will exert less resistance. DJs could be able to navigate songs more efficiently using this feature.

Textured-record-mode

Textured-record-mode adds a bumpy feel to the record. Rather than creating a haptic bump as in the *bumps for beats*-mode, these bumps influence the rotational speed and manipulate the output of the current song, slowing down the record every time it passes a bump.

Adding the missing turntable functionality

A standard turntable offers additional controls. Since the D'Groove turntable consists only of a rotating record, the authors tried to bring back the missing functionality by adding two more controllers (see figure 4.5) to the system.

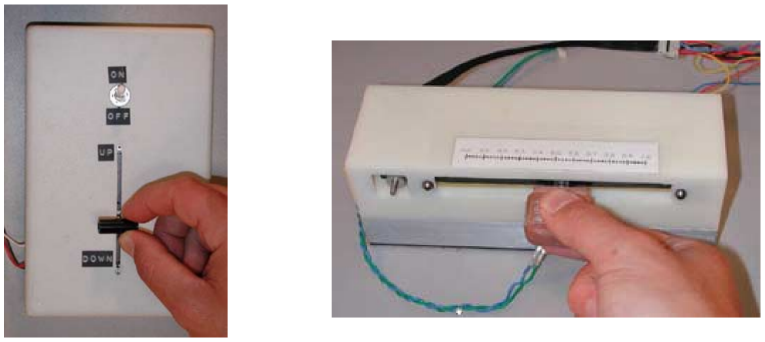


Figure 4.5: The D'Groove Pitch-slider (left) and Q-slider (right)

A pitch slider without limits

First of all there is the pitch-slider. Its the DJ's standard tool to change pitch and tempo of a song. But instead of just implementing a standard eight % slider, the authors exploited the digital nature of the D'Groove device, creating a slider that lets the DJ pitch the song infinitely.

The Q-Slider as a progress indicator and navigation controller

The presented turntable does not have a needle arm. This leads to several problems for the performing DJ. First of all it is hard to traverse big distances in a track. Secondly, there is no indication of the current position in the song. The authors present the Q-Slider, which looks like a pitch slider. This device acts as both, a progress indicator and a tool for navigation. The slider is able to move on its own, traveling along its one-dimensional axis with the progression of the song. By mapping the start of the song to the left end of the device and the end of the song to the right, the Q-Slider can accurately represent the song's current position. Additionally, it can be moved by the DJ to navigate inside the track. Because the Q-Slider is motorized, it gracefully maps the progression of music to its position, preserving the turntable metaphor.

Evaluation

Six professional DJs were invited to take part in a qualitative study. The authors wanted to explore if the D'Groove system "*had successfully captured the DJ experience*". After a short introduction, DJs were able to test the system and mix and scratch freely. Finally an interview was conducted with the participants.

Sound quality, latency and the red marker were received well

Sound quality and latency were adequate for most of the DJs since only one DJ claimed that he would notice a difference to traditional systems. Sadly, the beat markers printed on top of the record were not used for beatmatching at all. The DJs continued to rely on their ears instead of taking advantage of the visual feedback. However, DJs used the red line on the record to synchronize the phase when cueing beats. The white lines were not used at all.

The haptic feedback features of the turntable were deemed useful

While resistance-mode was not considered useful by the participants, the other three techniques were deemed useful performance tools by the DJs. Spring-mode was the most popular mode, providing the most fun for the participants. Bumps for beats was mostly used for scratching instead of navigating. Textured-record-mode helped the participants to perform a certain scratch move. The Q-Slider worked well for all participants, but they asked for a visual output of the song's mood on the device.

The D'Groove would be acceptable for DJs

The authors wanted to know if the D'Groove system would be an acceptable alternative for the common DJ. Most DJs responded positively to the D'Groove, stating that they would be willing to use it on stage if the system "*was more durable, had a higher turntable torque and combined all the components into a single device*". Since the DJ stays in control when using D'Groove, this kind of performance aid would not be considered cheating.

In Conclusion: a powerful new performance tool

All things considered, the D'Groove is a new and powerful performance tool that stays true to the turntable metaphor while enhancing it with new haptic features. The decoupled controls (Q-Slider / Pitch-Slider) did not pose a problem to the DJs when they performed. But the overall appearance of the system, as well as the setup, call for a single device integrating all of the features in a sturdy and robust manner.

4.5 Vinyl+

Vinyl+ (Bohatsch [2010]) is an art installation by Jonas Bohatsch. It features an interactive record which is projected

Figure 4.6: Vinyl+

with a visualization of different elements which can be activated when the needle "touches" them (see figure 4.6).

Changing shapes and sounds

The shapes on the record change according to position and rotational velocity, allowing the user to manipulate the sound that is being produced. Although there is no real musical output, the setup creates a unique kind of sound. Whenever the needle touches an element of the visualization, it creates a plopping noise.

Art

Because Vinyl+ is an art installation it provides no support to DJs. It produces sounds but can barely be considered a musical instrument in the common sense. But it is a new kind of input device, fusing the analog and digital world into one device.

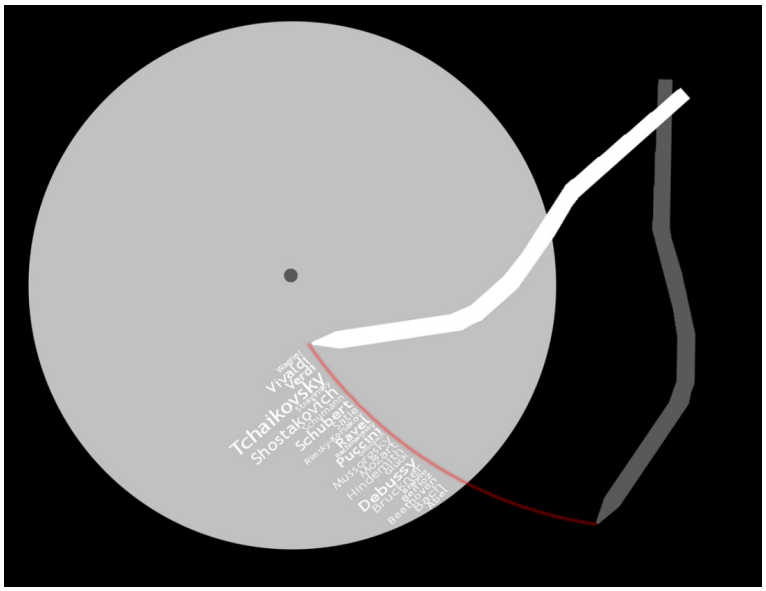


Figure 4.7: TIMBAP - Tag cloud for searching

4.6 A Tangible Interface for Music Browsing and Playback Manipulation (TIMBAP)

Pabst and Walk [2007] presented *TIMBAP*, a device that enabled the DJ to browse his digital music library and to manipulate the playback of digital audio files. Both functionalities were integrated into the turntable to eliminate the use of mouse, keyboard and computer screen. Therefore the DJ can use the record as the only device for control and information since it also offers feedback through a projection from the top. The overall system relies on timecode vinyls and MsPinky[1] to process the timecode.

Goal orientated search

After an analysis of the user's search task (browsing traditional vinyl), the authors came to the conclusion that most DJs do not aimlessly search their record crate. Most of the DJs are looking for the cover art of the record they want to find. Although the place in the crate, artist and title are also important for most DJs, TIMBAP concentrates on display-

[1] http://mspinky.com/

ing the cover art.

Aimless browsing

To facilitate the user when looking through his music library, the authors implemented the *aimless browsing*-feature. Using the rotation of the turntable, the visualization browses through the songs of the library, showing each cover art. Stopping the record will also stop the browsing. By this, the "*visualization metaphor presents items as a list on a conveyor belt*". Keeping an item in focus will start the track and expand the cover art onto the record. Stopping the record for a short amount of time will minimize the cover art and the DJ can return to browsing.

Tag-Cloud browsing

But DJs are usually searching for a specific track. Aimless browsing might not be the best method to locate a certain song in a big library, since it is only a one-dimensional interface. Using the tonearm as a pointing device, another tool is available for the DJ. TIMBAP scans the music library of the DJ and is able to arrange songs according to tags. These tags can then be displayed on the vinyl in *Tag-Cloud*-mode (see figure 4.7), offering high level browsing and therefore increasing search performance. Because only one search criterion can be displayed on the vinyl, the user can switch to a different one using scratch gestures.

A promising system

TIMBAP is a promising system, completely eliminating the computer as an information and control device. DJs could stick to their turntables and would still be able to browse and manipulate digital music. It could point the way to a DiskPlay version without a computer screen.

Chapter 5

Design

The following chapter will describe the design process of the new DiskPlay implementation. First of all, it will describe which problems were tried to solve and how DiskPlay should be able to support the DJ. Later on, this chapter will concentrate on ideas for features that could be added to the system as well as choosing a new base application on which DiskPlay can be built upon. During the whole design process, the turntable metaphor has to be kept in mind to present a natural visualization, thus working with the turntable and not against it.

Ideas and solutions taken from chapter 3 “Comparative Turntable Studies” and chapter 4 “Related Work” will be highlighted to create a connection to the presented work.

5.1 Basic Design Principles

Avoid creeping featurism

When adding features to an existing system, one always has to keep in mind that the system has to be usable afterwards. Donald A. Norman has coined the phrase *”creeping featurism”* (Norman [2002]). It basically describes the process of adding and adding features to a product until it too complicated to use. *”With extra features comes extra complexity. Each new feature adds yet another control, or display, or*

introduction". DiskPlay is designed to provide a slick interface, presenting only a minimum of information. The visualization must not be stuffed with features to avoid overloading the visual channel of the DJ.

Utilize available screen space

Moreover, screen space is precious. Jakob Nielsen (Nielsen [2011]) dedicated an article on his alert blog to this problem. He argues that although screen space "*is extremely valuable*" it "*shouldn't be hoarded, it should be spent*". The information that should be provided by DiskPlay must be clearly visible, not crammed into a small space. DJs should be able to read and see it while standing on the other turntable. Also the whole record should be used as a display, utilizing its full potential.

Problems of a DVS

In the same way as the old DiskPlay, the new DiskPlay implementation focuses on the enhancement of digital vinyl systems. Chapter 2 "Digital Vinyl Systems" describes several problems regarding a standard DVS:

- Separation of information and control
- No song information on the vinyl
- Random access browsing with the needle arm
- No cuepoints on the vinyl anymore

Heller and Borchers [2012] provided several great solutions for some of these recurring problems, focusing on "*appropriate visualization of the song*" and "*helping to navigate through the song*" (Lauten [2011]). To bring back the information to the vinyl, it is projected from the top with the output of an additional application. Since a new hardware prototype incorporating a display inside a turntable is currently out of range , this thesis will concentrate on enhancing this visualization.

5.2 DiskPlay - Missing Features

DiskPlay as a DiskPlay prototype

Instead of conducting initial interviews, the results of the

past implementation are taken into account. There are a bunch of opinions from several DJs regarding missing features of the visualization. They can take direct influence on the current system, since it resembles the last one and tries to enhance it.

5.2.1 Finding Beats visually - the Waveform

Waveform provides overview and visual cues

Every DJ needs to be able to find the exact beat that she is looking for. To provide an overview of the current song position's surrounding , commercial solutions use a waveform display. In Lauten [2011] a DJ specifically asked for a waveform display to be integrated into the visualization. Although only one DJ was directly asking for this feature, all of them "*made heavy use of the waveform representation to find a beat*". This may suggest that the waveform display is a crucial visual cue for the modern DJ. Not only does it provide information about the immediate past and future of the current playback position, but also a visual representation of the songs structure. This enables the DJ to find a certain beat or drop visually, without using her ears, thus possibly relieving the audio channel of it's heavy load. Bryan and Wang [2011] presented a similar display using a mobile phone as a screen.

The detail of the waveform

Waveforms are versatile tools. Their detail can be adjusted according to the needs of the user. *Serato Scratch Live* offers different levels of detail, zooming in and out of the waveform. Since most MP3s are sampled at 44.1 kHz, it would be possible to provide 44100 data points per second for the waveform. To set the correct zoom level, one has to keep in mind where the visualization should be able to help the user.

Waveform 1st iteration - horizontal scrolling

Figure 5.1 (left) illustrates phase one of the design process. The waveform was envisioned as a horizontal scrolling display, moving from right to left. Pabst and Walk [2007] states that these interfaces use a "*conveyor belt metaphor*". The center of the record is considered as the present, which means the current beat can be seen on the motor shaft. This kind of visualization has the advantage that it leaves room for

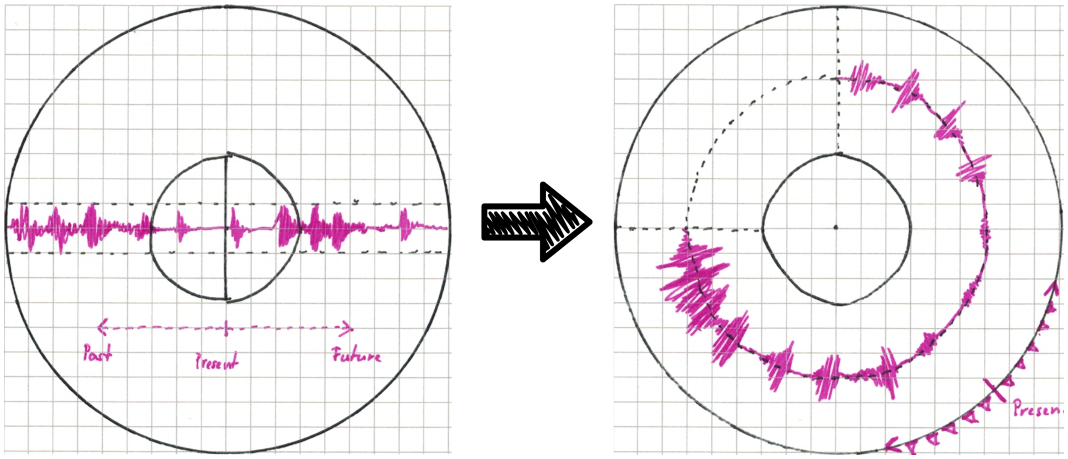


Figure 5.1: Wafevorm Design Iterations: first iteration (left) and second iteration (right)

the original song length visualization and the cuepoints on the record, only taking up space on the left and right side of the record. Additionally, it would be possible for the DJ to scale the waveform as she pleases, making the interface customizable for her needs.

Waveform 2nd iteration - mapping waveform to actual sound position

One of the basic design goals was to keep the turntable metaphor in mind. Figure 5.1 (right) shows the second iteration of the waveform display. Instead of a horizontal scrolling (conveyor belt) interface, Schriever [2010] implemented a circular scrolling display. Although a monitor is used as the output device, this kind of visualization could hold many advantages over the horizontal one when presented differently. In case of DiskPlay, the record is used as the display. This opens up the possibility to show the waveform at the needle position, mapping visual and optical output to the record. Thereby the turntable metaphor can be strengthened. In the same way as Bohatsch [2010], where the needle produces the sound when touching the elements on the record, the waveform moves through the needle position producing the sound.

Fixed mapping of waveform

This also gives an answer to how much time the waveform should display. Since a standard 33 RPM record takes about 1.8 seconds for one turn, it also holds the equivalent of musical data. Immediately the idea comes to mind to

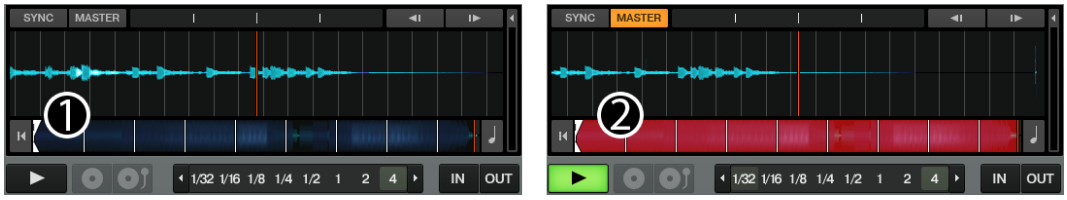


Figure 5.2: Traktor Track Ending Alarm - 1: Normal — 2: Highlighted

map the exact time to waveform. Moving the record half a turn will also move the waveform half a turn, thus adding an additional visual cue for the rotation to the vinyl. But there is also a downside to this. If the mapping is fixed to the records rotation, then the waveform can not be zoomed or customized anymore. But since one of the basic design goals was to stay true to the turntable metaphor and its natural control, it was decided to fix the mapping to the rotation of the vinyl and therefore fixing the visualization to its rotational position.

Closed waveform

The second iteration of the waveform features a hole in the top left. Initially, this position was intended for a special purpose display (see chapter 5.2.3 “Cuepoint Progressbar”), which was repositioned later on. This gap was closed with the waveform, creating a complete circle. The additional screen space was utilized just as Nielsen [2011] suggested, thus providing more information.

5.2.2 End-of-Track Warning

DJs need song ending alerts

In Heller and Borchers [2012] a DJ states: *”The most embarrassing thing that can happen to a DJ is that the song is over without him noticing it and therefore has no time to create a smooth transition by beatmatching”*. Every professional DJ product offers a simple solution for this: Some kind of flashing display, a warning to catch the DJs attention. *Native Instrument’s Traktor* adds a blinking animation to its waveform song overview (see figure 5.2). Another DJ added: *”something flashing would be nice”*.

First iteration: The blinking waveform

Since a song overview in form of a mood representation is not finding its way into the new DiskPlay interface (see

chapter 5.3.1 “Song overview”), another way of warning the DJ must be found. The first idea was to change the color of the waveform, making it blink back and forth between a highlight and its standard color. But this poses a problem if the last bit of the song is very quiet, thus only a small waveform is being drawn. As a direct result, the warning that was intended to be an eye catcher becomes a small blinking line and therefore an unsuitable alarm display.

Second iteration: The blinking record

To produce a consistent song ending alert, there must be a consistent area for it to be displayed. The song visualization provides such an area. If the complete song length and the ”empty” part of the record are used, the resulting surface should be big enough to catch the attention of the DJ. Flashing surfaces are not very pleasing to the eye. It is important that the alarm does not blink too fast or too often. Additionally it should not start too early to enable the DJ to work normally with the system. In the end, the threshold for the alarm was set to 30 seconds, changing the colors every half of a second.

5.2.3 Finding Cuepoints

Finding cuepoints is hard using the absolute mode of a digital vinyl system. There are no hints on the record and the focus switches between vinyl and computer screen when navigating a track add to this problem. The last DiskPlay version presented a suitable solution for this nuisance. Just as DJs used stickers on the vinyl, visual stickers are projected onto the record. Adding an orbit to the cuepoints provides another visual cue to the DJ. But the authors encountered additional problems. The resolution of the projector can not match the real world equivalent of a vinyl. Therefore, one DJ had problems finding the cuepoint after the needle drop. Since the tonearm is a coarse navigation tool, there should be more aids for the DJ. Lauten [2011] states that the DJ ”*did not know if he had to spin one, two or three times, before hitting the cuepoint*”.

Help on different levels

Upgrading the projector and therefore the resolution does not seem to be the solution. Even with a device providing

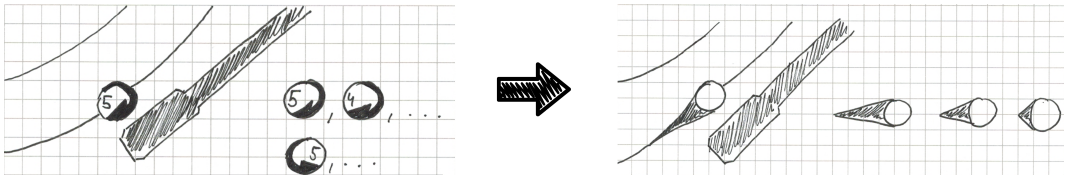


Figure 5.3: Cuepoint visual aid - first (left) and second iteration (right)

double the resolution, the grooves would not be locatable. While the cuepoint and orbit provide a coarse visual cue on where to drop the needle, there should be different levels of visual aids guiding the DJ to her target.

First iteration: cuepoint-labeling

Figure 5.1 (left) shows the first iteration of the second level cuepoint help. Whenever the needle is near such a marker, additional information should pop up inside of it. Instead of just painting the cuepoint with a solid color, a small arrow indicating the direction in which to rotate and the number of rotations to reach the cuepoint are displayed. But this kind of visualization is unfit for a turntable. First of all the tonearm can overlap the cuepoint when it is right below the needle. Additionally, it became clear that the record is spinning way too fast to enable the user to read the number. The cuepoints are just too small. Making them bigger is only partially helpful.

Second iteration: pointy cuepoints

In the second iteration (see figure 5.3 - right) the labeling and the arrow were removed. Instead, the cuepoints were made pointy. The thorn was pointing into the direction the DJ had to rotate, shrinking and growing with the distance to the cuepoint. Although there was no number to read, it was hard to follow the cuepoint around the record, especially when the vinyl is rotated rapidly.

Cuepoint Progressbar

The problem was more or less that cuepoints needed to be small so they would not take up too much space. Since they are fixed to the rotating vinyl, they have to be traced with the eye. A stationary widget displaying the distance to the cuepoint would be much more suitable. Figure 5.4 illus-

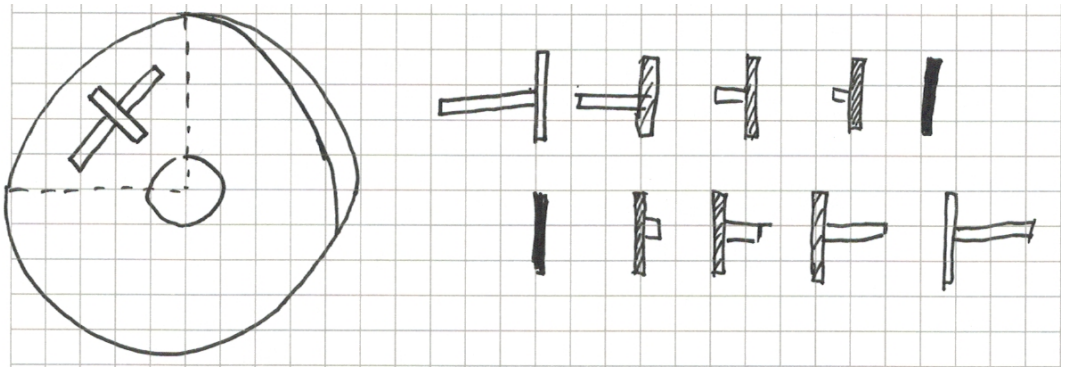


Figure 5.4: Cuepoint visual aid - third iteration

trates the idea of a cuepoint progressbar. Leaving a gap in the top left of the waveform, the progressbar was rotated by 45° and put in place. There is no need to look for the cuepoints to get information. The record can be rapidly rotated and the distance to the cuepoint can be determined by looking at the progressbar.

One bar changing in color, the other in size

The widget consists of two bars. There is one bar in the middle representing the cuepoint. It is fully opaque when the needle is on top of the cuepoint and translucent when it is far away. When the needle approaches the cuepoint the color starts to fade in. The bar is surrounded with a stroke when the DJ reaches the cuepoint to assure her that the color is in fact fully opaque now and the task is complete. The second bar visualizes the distance to the cuepoint. In the same way as the thorn of the pointy cuepoints, the bar shrinks and grows with the distance to the cuepoint.

Positioning the bar in the locus of attention

In the last step of designing the progressbar, it was moved to the locus of attention - to the needle. Since the tonearm is blocking the right side of the needle, the progressbar is moved to the left of it. Putting the widget below or over the needle would require a change in position when the tonearm is moving slowly over the record, which is not desirable since it is easier for the user if it stays in one place.

Show it when it's needed - hide it otherwise

The new progressbar is only useful when the needle is close to a cuepoint. For this reason, it should not be visible if the distance is beyond a certain threshold and screen space can be freed up when it is not used. The threshold

was set to eight seconds, which is roughly the width of the orbit.

5.3 Other Basic Design Choices

5.3.1 Song overview

Most professional DVS systems offer a song overview. Figure 2.4-1 shows such a song mood representation as it is shown in *Serato Scratch Live*. It is composed of brighter and darker areas. High energy parts can be identified easily by looking at the vivid areas, low energy or quiet parts are located in the fainter areas. This gives the DJ a good visual hint where to look for specific chunks of music.

No song structure on the timecode vinyl

In the analog age of the traditional vinyl, this kind of information was visible on the record itself. Timecode vinyls can not support this kind of feature with a generic record. Lauten [2011] mentions that all DJs that have been interviewed *"agreed that this information is lost with timecode vinyls"*.

Put the mood back on the record

Because this kind of visualization can easily be built as a waveform with a very low sampling resolution, it could be easily integrated into the system. But where should the song overview be displayed? Surely there is unused space in the center of the record. Considering that there should be a direct mapping between music and visualization, the only correct place would be to put it on the record. Figure 5.5 shows an early design approach to this problem. A static display that could be shown on the record which presents the mood of the song where it would actually be found.

No space on the record

Positioning this bar on the record was one of the biggest problems, since the waveform takes up the space on the vinyl. The overview should also be moved right below the needle to enable the DJ to navigate by dropping the tonearm onto the right position. Only one of the two widgets should be constantly displayed.

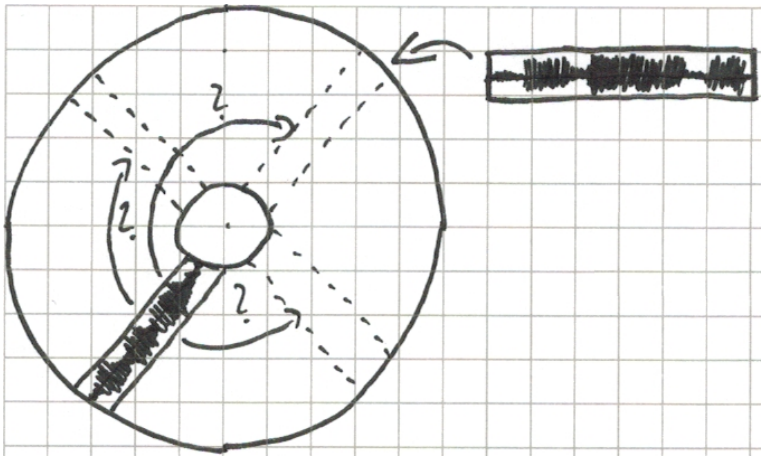


Figure 5.5: Song mood representation - first iteration

Changing modes?

A different idea came up. The mood representation is only important for coarse track navigation. Since this is mostly done by moving the tonearm, it could introduce two different modes for DiskPlay. When the needle is dropped, the standard rotating waveform is displayed. Picking up the needle changes the mode to song overview, hiding the waveform below the needle and displaying the song overview. After all, this would require some kind of additional hardware, maybe a switch that is attached to the tonearm, which would be used to change modes. A timed interface could also be implemented. Whenever the record is not moving for a certain period, the mode could be switched to song overview.

No mode switches for this version - no mood representation

Changing modes through a timed interface can interfere with the user's workflow. Imagine a DJ that has cued up a beat, stopping the record and waiting for the perfect moment. If the mode changes to show the song overview, the DJ could be distracted. Additionally the information provided at this moment would be of no use to her. The second variant using an additional switch would also require additional hardware in form of a small *Arduino* or other USB device to be integrated into DiskPlay. This could be promising for future work and will be discussed in the last chapter. In conclusion, there is only room for one waveform display. The moving waveform provides more benefits than

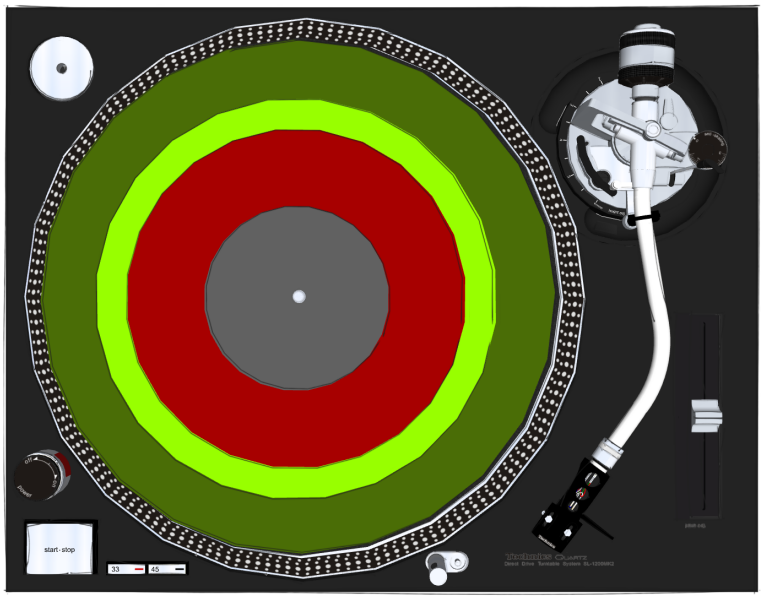


Figure 5.6: Final colorscheme of DiskPlay

the song overview which is why the mood representation is not integrated.

5.3.2 Colors

The colorscheme for DiskPlay has to fulfill certain criteria:

- Colors have to be meaningful
- Colors need to be sufficiently distinguishable
- Colors need to be visible on the projector

Colors for the song visualization

The song visualization on the record needs to convey the idea of what is past, what is to come and where the needle is not supposed to go. Green and red are colors that are uniquely suitable for this task. Green suggests "go" or "yes", while red acts just as a stop sign. Accordingly, the DiskPlay colorscheme is made up of these signal colors (Figure 5.6). Red is chosen for the center of the record

which will not map to any musical playback since the song is shorter that the timecode vinyl. Two shades of green are used for the song itself. The dark green maps to the song's past, the bright green to its future. The border between both depicts the present - the needle's position.

Colorcoded cuepoints

Cuepoints can be set in the host software. *Scratch Live* uses colorcoding to make each cuepoints easily distinguishable from the others. To simplify the identification on the record, the color of the cuepoints is mapped to the color in the software.

5.3.3 Song identification

Show which song is currently playing

Traditional vinyls offer dedicated cover arts and stickers to identify which record is currently being played. DiskPlay needs a similar feature to enable the DJ to see which track is currently loaded in which deck. Pabst and Walk [2007] presented a system which used the cover art of a song and projected it onto the complete vinyl. Based on the assumption that DJs browse their crates, looking mainly for the cover art of the record, this was a good idea for browsing songs. But with the introduction of MP3s, cover art is not always included. Additionally, browsing is rather done my looking through text-based lists or searching in a text field. The cover art lost part of its importance.

Cover art vs. text

Basically, there are three options to present a unique identifier on the record. Either the cover art is displayed and/or the artist and title as text. To keep the visualization clean, DiskPlay only uses artist and song title, which is displayed in the center of the record. This location offers the required room for long titles and is the traditional location for this kind of information.

Text is not turning

Although traditional turntables force the whole record to rotate, DiskPlay's artist and title should stay static. On the one hand a turning display would provide a more immersive experience, but on the other hand the static display will offer far better readability which is preferable in this scenario.

Figure 5.7: An extra area for additional song information

5.3.4 Other displays

A BPM counter?

When performing, some DJs heavily rely on the BPM counter to match the speed of one song to another. It does not require the DJ to hear the actual songs to correct the speed of them. Still, the phase of the incoming song has to be matched, but some DJs still consider this approach as cheating, since it does not involve using the ears as a tool. Heller and Borchers [2012] state that two DJs asked for such a BPM counter to be added to DiskPlay.

Show absolute time of songs?

Three other DJs asked for a display showing the absolute time that remains of the track. This kind of visual aid does not count as cheating by any means. Considering that DJs need to take bathroom brakes too, it could be a good idea to integrate this kind feature.

Screen space is still precious

Adding yet more widgets to the system will also use up more space. The record is already completely filled with various visual aids. But instead of adding more widgets to the vinyl, one could add another area to the turntable on which information can be projected. Figure 5.7 illustrates

one possible location for an additional display. A slightly slanted white piece of cardboard or plastic could be used but would have to be elevated to match the focal point of the projector.

No additional displays

Although many DJs would like to see a BPM counter or the absolute time on the turntable, it was decided not to add other displays to the final implementation. First of all, the projection area would be mounted on the top left, since it is the only spot which provides enough room. Other areas on the turntable are either blocked or the small platform would interfere with other parts of the deck. This moves the display out of the locus of attention, requiring the DJ to look further to the top left of the turntable. Considering that this is still an improvement when compared to a focus switch to the monitor, it might be a minor issue. But adding extra displays to the DiskPlay setup might just be a feature which can be taken a pass on. It does not integrate well into the current design approach, projecting numbers onto the turntable.

5.3.5 Absolute mode only

Today's digital vinyl systems feature two playback modes: absolute and relative. Relative mode analyzes only playback speed and direction. Absolute mode additionally decodes the position of the needle on the record. While relative mode provides the possibility to instantly jump to a cuepoint with a press of a button, absolute mode allows for in-track navigation using the needle arm.

Use the tonearm - no relative mode

DiskPlay wants to make use of the needle arm as a powerful input device, mapping needle position to song position. Relative mode would interfere with the visualization and is therefore not an option. Some systems integrate a *drop to absolute position*-feature which allows DJs to use the tonearm as a navigational tool in relative mode. By this, the DJ can still jump to a cuepoint by pressing a button. Although this would improve the interaction possibilities of the DJ, it would also lead to inconsistency whenever she jumps to a cuepoint.

5.3.6 Customization

DJs are always looking for new ways to customize their setups. Therefore DiskPlay should be customizable as well. This includes being able to change the color of the visualization as well as turning features on or off. Additionally, there should be a feature that enhances the visual output on black timecode vinyl, using a grayscale colorscheme.

Chapter 6

Implementation

This chapter will describe the implementation process of the new DiskPlay application. It will start off with a description of the host software and why it was chosen. Next, there will be a short explanation why Quartz Composer was not used as the base framework and which problems were encountered. The main part of this chapter will describe the overall architecture of the project and present some parts of the implementation.

6.1 Host Program

Heller and Borchers [2012] chose *Mixxx* (Andersen [2003a]) as the host program for their DiskPlay project. Mixxx provided an open API, offering full access to the information of the song and the program itself. But it did not provide the slick and professional user interface that DJs are accustomed to. Additionally, most DJs never worked with Mixxx before.

Traktor versus Scratch Live

There are basically two big companies today dominating the digital vinyl market. *Native Instruments* produces *Traktor*[1] and *Serato* produces *Scratch Live*[2]. While Traktor might

[1] http://www.native-instruments.com/de/products/traktor/
[2] http://serato.com/scratchlive

be the most popular solution today, it is also closed shut. There is no API or plugin support besides several music library plugins, which do not access Traktor itself. This was the case for Scratch Live too. But Serato released *Serato Video*, a VJing plugin for Scratch Live.

Serato Video supports Quartz Compositions

Intended as an integrated VJing solution, Serato Video offers one video deck for every audio deck. To give VJs a new tool for an interactive performance, it also offers Quartz Composition support. This allows for the creation of music reactive videos.

6.2 Base Platform - Scratch Live

Since Scratch Live was the only professional system that offered at least some kind of access to its data, it was chosen as the base playback and host program for the new DiskPlay implementation. Serato Video should be used as the interface to get information and data out of the host program. When the plugin is activated, it creates a new *openGL*-accelerated window which can be presented via a projector.

Videos can be fixed to songs

Tracks can be prepared easily by binding a video or Quartz Composition to the file, so every time the song is loaded into a deck, the video is loaded into its corresponding video deck.

6.2.1 Serato Video and Quartz Composer

Input patches suitable for a basic visual output

Serato Video offers several different input patches for Quartz Composer (see figure 6.1). These input patches provide sufficient information for a simple video output showing song, artist and the basic track visualization. Sadly, all input patches provide only a snapshot of the current song. Although the collection provided by Serato does not offer access to the Scratch Live's waveform or song mood display, the path of the source file is available. This opens up

Figure 6.1: Serato Video Input Patches

the possibility to analyze the song independently of Scratch Live.

6.2.2 Challenges for Data Acquisition

Because of Serato Video's limited interface, there are two basic challenges regarding data acquisition:

- Cuepoint data
- Song data for the waveform

Get cuepoints by OCR

There is no direct way to get access to the digital cuepoints. The cuepoints can only be placed directly in Scratch Live. Although the application supports external MIDI-controllers, these devices can only jump to a certain cuepoint or mark a cuepoint. Therefore the MIDI interface is not of any use. Another option would be to do optical character recognition (OCR).

Build waveform by analyzing the audio file

Scratch Live saves new song information directly to the MP3 file. This information can be found in several hidden MP3-tags. After analyzing the data in the hidden MP3-tags, it became clear that Scratch Live builds the waveform of the track on the fly when it is being played, saving only the song overview as a hidden tag. The waveform has to be created by accessing the currently playing audio file and do an extra analysis.

6.3 Implementing DiskPlay in Quartz Composer

Quartz Composer is a tool for processing and rendering graphical data and since Scratch Live supported Quartz Compositions, it was chosen as a the main framework for DiskPlay. The final Quartz Composition could be bound to songs in Scratch Live and be displayed by Serato Video. There would be no need for an extra application and it would gracefully integrate into the DJ setup. There would be no need for any configuration or installation.

6.3.1 Inflexible and Instable

Serato Video is instable and inflexible when outputting Quartz Compositions

Sadly, a prototype revealed that Serato Video is quite unstable when complex Quartz Compositions are being played. Even after several attempts with different patches, no solution for this problem could be found. Additionally, some patches were not supported by Serato Video. They were ignored and not being executed. Various attempts were made to get in contact with the plugin developers but no information on this issue could be gathered. Since the waveform and cuepoint data had to be acquired, some custom patches had to be included into the Quartz Composition. Quartz Composer did not provide appropriate objects for this task in its library. Finally, Quartz Composer was dropped and other means of presenting DiskPlay had to be found.

6.4 DiskPlay: A Standalone Networked Application

Since the initial Quartz Composer prototype was proven to be inadequate, it was decided to implement a standalone application for DiskPlay. But still, the information has to be taken from Scratch Live.

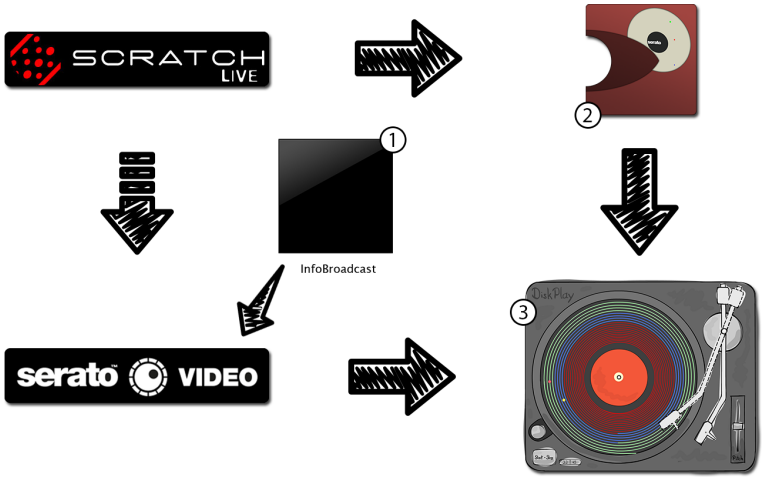


Figure 6.2: DiskPlay architecture overview: 1: InfoBroadcaster Patch — 2: Cue-Point-Feed application — 3: DiskPlay application

6.4.1 Architecture Overview

DiskPlay contains three components

The new DiskPlay system consists of three components (see figure 6.2): First, the *InfoBroadcast* Quartz Composition that is loaded as a video in Scratch Live and will pipe out information about the current song. Then there is the Cue-Point-Feed application that will do optical character recognition and recognize the cuepoints. Finally there is the DiskPlay application producing the visual output.

6.4.2 InfoBroadcast

A Quartz Composition using multicast

Figure 6.3 illustrates the first of the 3 components of the system. The InfoBroadcast-patch is loaded and bound to audio-files. It will pipe out the song's length, file-path, artist, name and current time. To make the information accessible for the DiskPlay application, a *network broadcaster*-patch is used. The patch uses *UDP* to either *broadcast* or *multicast* an incoming string. Using *multicast*, the information is being send over the network to any computer that is part of the same *multicast-group*. While the patch time is transmitted synchronously, song path, length and artist

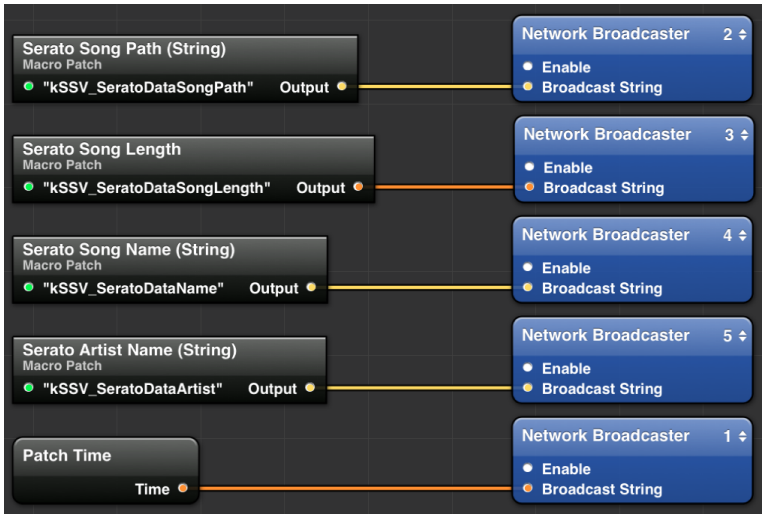


Figure 6.3: Info Broadcaster Patch

are refreshed 100 times per second. Although most of the presented update intervals could be longer, using shorter intervals does not have a bad impact on the performance. Updating the song time synchronously is of utmost importance to provide the lowest possible latency for the visualization.

6.4.3 Cue-Point-Feed Application

Standalone Cue-Point-Feed application using multicast

ScratchLive does not offer any interface to get information on the marked cuepoints. Hence the Cue-Point-Feed application was implemented in Quartz Composer to be used as in the same Quartz Composition that should be loaded into the video deck. Since it became clear that the Serato Video plugin was not stable, the Cue-Point-Feed composition was embedded into a dedicated application, making it independent of the actual DiskPlay application.

Getting the Screen's Output

Periodical screenshots are sufficient

To get information on the cuepoints, screenshots are peri-

odically taken. The *v002-Media-Tools*[3] offer a screen capture module that is capable of capturing the display's output in real time. Cuepoints will not change too often. They are mostly set when preparing for a DJ session. But even when they are set while performing, there is no need for real-time data acquisition. Making only periodical recognitions additionally saves resources.

Getting the Cuepoints Screen Location

Different GUI arrangements

Scratch Live offers different GUI arrangements, therefore the cuepoint information area will also change its position. The Cue-Point-Feed application was built in a way that every arrangement should be usable by the DJ. There is only one restriction for the DJ - use Scratch Live in fullscreen-mode. It simplifies finding the cuepoints on screen. The area which contains the timing information will always be at the same location in a certain setup. There is no need to find specific features on screen to determine their location. Determining which arrangement was chosen by the user is quite simple. It can be selected on the top left by pressing one of four buttons. To get the location of the cuepoint area, it is sufficient to determine which button is highlighted.

Character Recognition

Figure 6.4 shows the process of the actual character recognition. After the position of the cuepoint timing information has been determined, every row will be analyzed. One row contains five numbers with additional spaces between minutes, seconds and a tenth of a second. The accuracy of the textual output specifies the accuracy of the cuepoints of the visual output.

Restricted scenario

Since the size of the font and the font-type will be the same in every setup, the recognition scenario is restricted. It is sufficient to check several sample pixels for their brightness values. In the case of the Cue-Point-Feed application, the

[3] https://github.com/v002/v002-Media-Tools

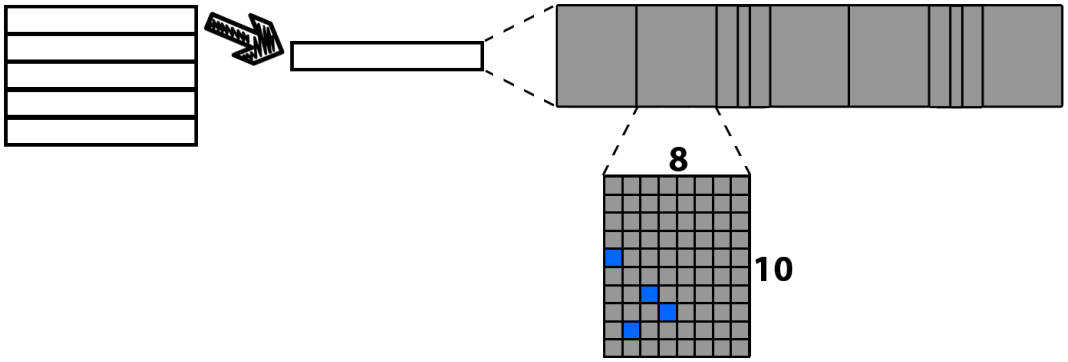


Figure 6.4: Detail of Cuepoint Optical Character Recognition - the four important pixels are highlighted

red channel of the pixel is analyzed. To use as little processing time as possible, it is important not to check too many pixels. Four pixels have proven to provide enough information to determine the number in every cell.

Four pixels to determine all number

The first pixel that is being checked is located at (0,4) and will recognize 0,5 and 6 by their red component. Step two will recognize 1,4,7 and 9 at (2,6). 2 will be determined at (1,8) and finally 3 and 8 are recognized at (3,7).

Sending the information to DiskPlay

In the last step, the information is coded into a string and sent to DiskPlay. A *network broadcaster*-patch is inserted to use yet another *multicast group* to pipe out the information.

6.4.4 The DiskPlay Application

The new DiskPlay application was built using Apple's *Cocoa* framework. It was coded in *Objective-C* and requires at least OS X 10.7. Using the Cocoa framework provided more flexibility when it comes to control flow and adding features.

There are four components in the DiskPlay application:

- `AppDelegate`
- `MusicInfoExtractor`

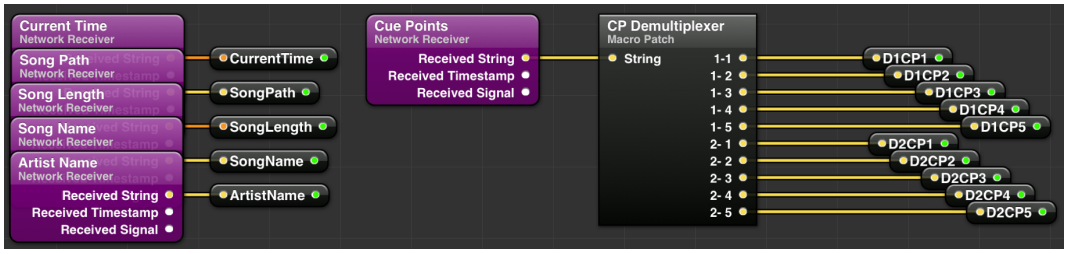


Figure 6.5: The InfoReceiver Quartz Composition

- *infoReceiver Quartz Composition*
- `SelectionView`

The `AppDelegate` is the main class, creating one `MusicInfoExtractor`, the `SelectionView` and a `QuartzCompserView` hosting the *infoReceiver* Quartz Composition. It will also handle loading and saving states from and to *PLists*.

InfoReceiver Quartz Composition

Receiving network information

The *InfoReceiver* Quartz Composition (see figure 6.5) is receiving all information from the *InfoBroadcast* Quartz Composition and the Cue-Point-Feed application. It connects to the *multicast groups* and provides several string outputs. Although it is a Quartz Composition, it produces no visual output. To gain access to these strings, *Cocoa bindings* are used to bind the `QuartzCompserView` to the composition. Since the cuepoints are multiplexed by the Cue-Point-Feed application, they have to be inverse multiplexed when they are received. There is a small *macropatch* that divides cuepoints by a separator-string and provides one output per cuepoint for two decks.

SelectionView

CALayers are flexible and provide good performance

The `SelectionView` is a `NSOpenGLView` that provides the output for the DiskPlay application. It uses *CALayers*

that can bee freely arranged, moved and animated. *CALayers* are accelerated by *OpenGL* and provide sufficient performance and flexibility.

Sort layers according to tasks and behavior

CALayers can contain *CALayers*. By this, a hierarchy of layers can be set up to fit the needs of the programmer. If a parent layer gets resized, turned or moved, all of the children will be transformed as well. This allows grouping of layers according to their behavior and tasks. DiskPlay contains rotating and stationary widgets. After introducing a `rootLayer`, there are several child layers added.

CALayer hierarchy

A `stationaryLayer` and a `circleLayer` are providing the main visual output. The `stationaryLayer` will not rotate on its own and be the root layer for all widgets that have a persistent location on screen and are connected to the song's visualization. The `circleLayer` will contain rotating items of the visualization. Artist and song name will be presented using *CATextLayers*. These require a custom resizing policy and were added to the `rootLayer`. The waveform will require not only a custom resizing policy, but additional precomputing when the window size changes. Therefore it is added to the `rootLayer` inside the `pathLayer`. To offer screen calibration there is a `calibrationRootLayer`. It will have to keep the same size, position and angle and is also added a as separate component to the `rootLayer`.

SelectionView - Main Song Visualization

Main song visualization

One of the early steps in creating the new DiskPlay is the integration of the basic song visualization featuring three visual hints for the DJ (see 3.2.1 "Features"), mapping the song to the record. These were implemented using three different *CALayers* and changing their bounds and cornerradius according to tracklength and playback position . Figure 6.6 (left) illustrates the output in its final state, showing how much of the song has passed (dark green), how much is left (bright green) and where the record will not produce any output (red).

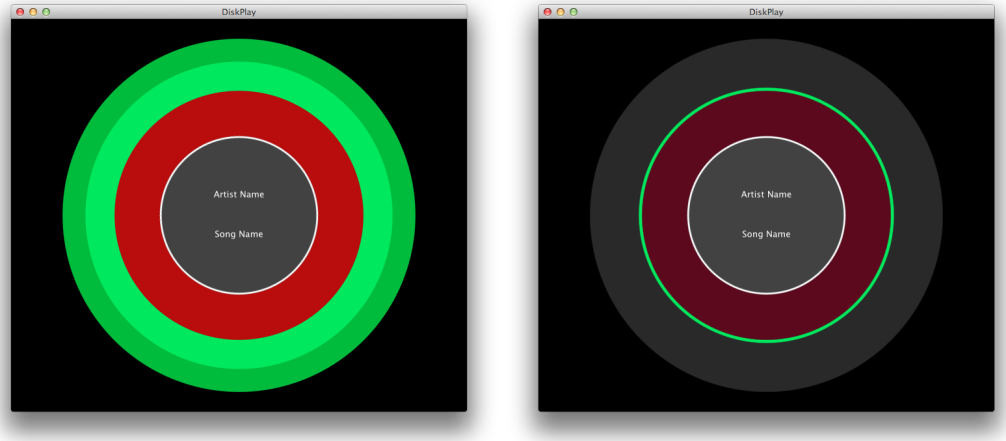


Figure 6.6: The DiskPlay song visualization - left: standard output, showing song length and current playback position — right: active song ending alarm when only a small portion of the track is left

Song Ending Alarm Changes Layer-Colors

As requested, there was a song ending alarm implemented (see figure 6.6 - right). It will trigger whenever the song has less than 30 seconds left. By changing the colors of the outer (dark green) layer and the center (red) layer, a high contrast blink effect can be produced while leaving the bright green circle as it is. The DJ can still see how much of the song is left. Additionally, the area of that is blinking will always take up about 97% since the timecode is 15 minutes long. Either the song is very short and the red area is taking up most of the space or the song is rather drawn out and the dark green area will cover most of the record.

SelectionView - Cuepoint Visualization

Two layers for every cuepoint

The cuepoint visualization uses two layers per cuepoint, which makes for ten layers in total. The top layer creates the small colored dot. They have to be positioned according to the information of the Cue-Point-Feed application. To get the preliminary X- and Y-coordinates, the cuepoints are positioned with respect to the current angle. X-coordinates can be calculated getting the sine of the current angle while Y-coordinates are calculated using the cosine.

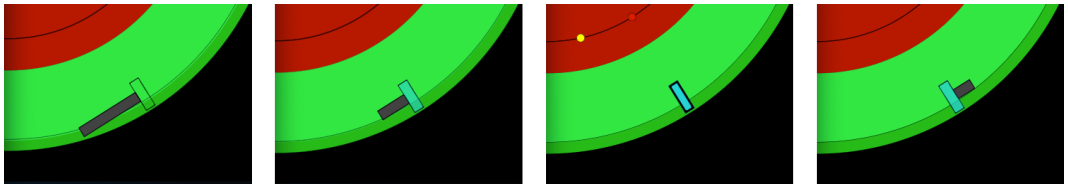


Figure 6.7: The cuepoint progressbar

Correct radius for time and size of vinyl

After the preliminary coordinates are determined, they have to be corrected according to timing information, moving them inwards or outwards. This is done by scaling the X- and Y-coordinate. Additionally, it is important to adjust for the current record. While the original timecode-vinyls of Scratch Live all share the same dimensions, there are other records that either stretch or compress the timecode on the record. To make DiskPlay more flexible, the coordinates are corrected for the size of timecode on the record.

Orbits just need correction for size of timecode

The second layer below the actual cuepoint stickers is used to display the orbit of the cuepoint. The layer is made completely opaque since it would cover the song information otherwise. It is then stroked in black. The orbit layers are always centered and are never moved. To get the correct location the radius needs to be changed according to cuepoint position and then corrected for the real size of the timecode.

The cuepoint progressbar

To provide the DJ with additional help, the cuepoint progressbar was added (see figure 6.7). It features a two bars with variable size. The bars will shrink when the needle approaches the cuepoint and grow if it moves away. This was accomplished by changing the bounds of the bar's *CALayer* and moving it to it's corresponding position when the screen is updated. A central area will slowly get filled with the color of the cuepoint. It will be fully opaque and get stroked, once the needle is roughly above the cuepoint. Because the Cue-Point-Feed application can only determine the cuepoint's time to the tenth of a second, the stroke will be displayed just as long.

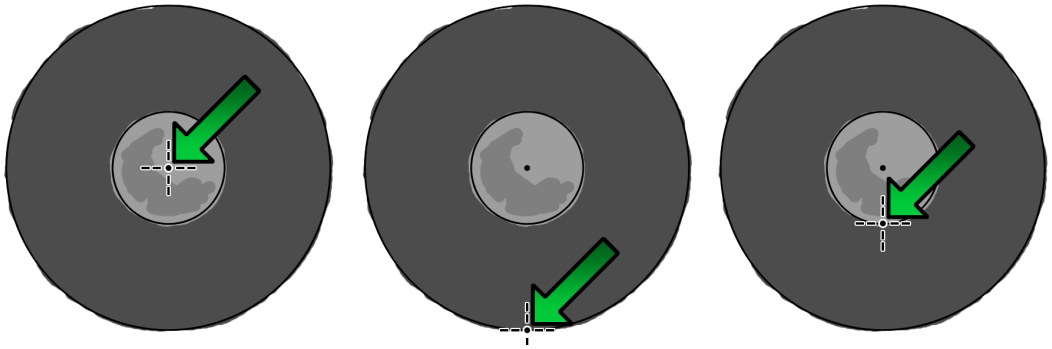


Figure 6.8: DiskPlay calibration routine sketches

SelectionView - Calibration Routine

Provide calibration routine

Just as the last DiskPlay application, the new version will feature a calibration routine. It is hard to position the projector in the correct height above the turntable. The center of the record and the center of the application do not easily line up. Additionally it is even harder to find the spot that provides full coverage of the vinyl. Several keys provide fine calibration to enable the user to do adjustments.

Three step calibration

After the DiskPlay application is positioned on the record, the coarse calibration is done by clicking with the mouse on certain locations on the vinyl. The calibration routine can be started from the menu bar. It features a simple three step calibration depicted in figure 6.8. In the first step the user is asked to mark the center of the record, moving the coordinates of the `rootLayer`. The second step determines the outer radius of the timecode and therefore the scale of the visualization. It is important not to mark the outer bounds of the record, since it contains an empty section at the beginning which will not contain any timecode data. Finally the user will be asked to mark the end of the timecode, thus defining the size of the playback area on the record.

Determine size of playback-timecode

Not all timecode records provide the same amount of timecode in the same area. Some of these records offer a special timecode zone in the center, near the label stickers. These special areas often contain control-timecode which enables the DJ to scroll through her library and pick songs. By let-

ting the user mark start and end of the timecode that is responsible for music playback, those records can be used as well.

Determine uiScaleFactor

The `uiScaleFactor` determines the size of the visual output. Whenever the user interface is rescaled, the `circleLayer`, `stationaryLayer` and `pathLayer` are transformed according to the new `uiScaleFactor`. The scale of the user interface can be determined by computing the length of a vector between center of the record and the start of the timecode.

Fine adjustment with the keyboard

To enable the user to do some fine adjustment, there are several keys to change not only the `uiScaleFactor` but also the angle (`uiAngleOffset`) of the visualization:

- R will rotate the output clockwise, L will rotate it counterclockwise
- $\leftarrow$ will decrease the size of GUI, $\rightarrow$ will increase it
- $\uparrow$ will increase the size very slowly, $\downarrow$ will decrease the size very slowly

Additionally, the key bindings can be displayed in a separate help window by clicking on the help menu item in the menu bar and choosing "show key bindings".

SelectionView - Drawloop

Timers are not accurate enough

The `SelectionView` contains the drawloop. It is triggered 60 times per second which allows for a constant framerate. In the first step a *NSTimer* was used to trigger the update of the output. But *NSTimers* are unfit for drawloops. Apple states that a *NSTimer "is not a real-time mechanism; it fires only when one of the run loop modes to which the timer has been added is running and able to check if the timer's firing time has passed"*[4]. The *"effective resolution of the time interval for a timer is limited to on the order of 50-100 milliseconds"*, which is not enough for a 60Hz refresh rate.

[4] Mac Developer Library - NSTimer Class Reference

CVDisplayLinks are accurate

The `CVDisplayLink` class offers a reliable way to implement a drawloop. `CVDisplayLinks` are part of *Core Video*. They create a separate high priority thread, that will check the current display if it is ready to refresh and needs a new image to display. Therefore, the rendering loop is bound to the refresh rate of the display.

Refresh information and update

Every time the `CVDisplayLink` triggers a redraw, it will execute its callback function. First of all, it will request new information from the *infoReceiver* Quartz Composition, updating song and cuepoint information. Next, all layers will be updated and redrawn.

SelectionView - Smooth Time

Problems with the rotation

One problem that came up when implementing the screen update was a stuttering motion. It was caused by missing timing updates from the *infoBroadcast* Quartz Composition. Having no new information, the rotating visualization came to a halt, not moving before it was provided with a new song time. An analysis of the number of updates per second revealed that an average of 30 timing updates were received. Sometimes only six updates reached the DiskPlay application, causing jumps in the visualization when new timings were received.

Smooth time

To get a clean output, the timing information needs to be smoothed. The record should move even when there is no new timing information reaching DiskPlay. A tradeoff between responsibility and visuals has to be made. The more the timing information has to be smoothed, the more fluent the animation will look. On the other hand, smoothing timing information produces latency.

7-3-2-1-1-1-1-1

Smoothing the time works as follows: There is a FIFO-queue saving the received samples. If a new time is reported by the *infoReceiver*, it will be put in front, removing the oldest item in the back. The newer a received sample is, the more relevant it will be to the current needle position. Instead of just calculating the arithmetic mean of all items in the queue, some of them are given an emphasis.

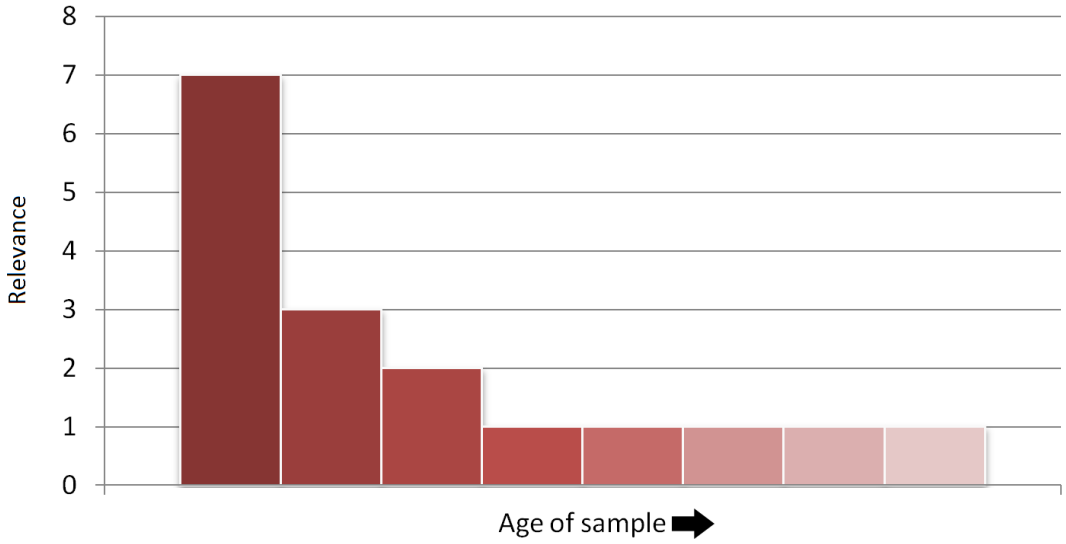


Figure 6.9: Time smoothing diagram

The relevance of the items is illustrated in figure 6.9. A strong emphasis on the first two items leads to more responsive feedback. Additionally it was decided to smooth over eight samples to compensate for very weak feedback from Scratch Live. The presented scheme offers a good tradeoff between latency and a clean visual output.

SelectionView - Waveform

DiskPlay features a waveform display to find beats. Sound is mapped to its position on the record. Just as Bohatsch [2010] presented an interface that produced sound when the needle touched certain items on the record, the needle will create sound according to the waveform that is traveling underneath it.

Four important steps to visualize a waveform

To visualize the waveform of an audio file, three tasks have to be accomplished:

- Acquisition of data
- Reduction of data
- Storage of data

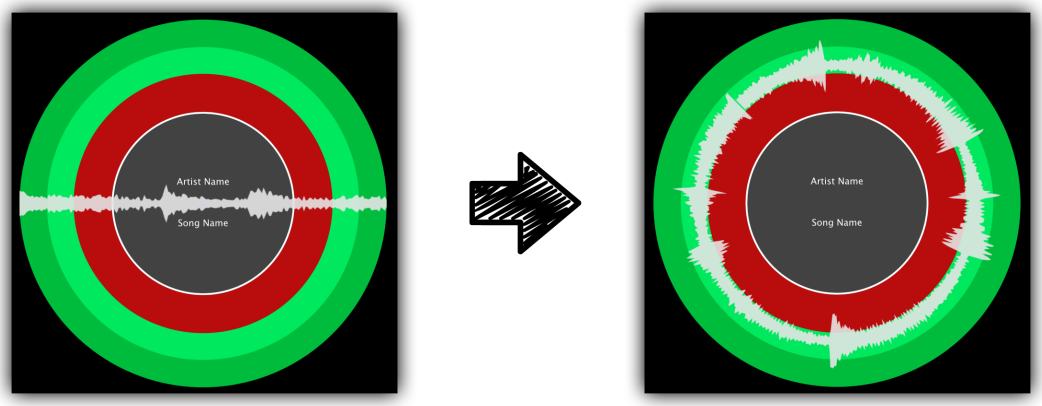


Figure 6.10: Different waveform displays - horizontal (left) — circular (right)

- Display

Since the `SelectionView` only provides the visual output, it will concentrate on displaying the waveform. The `MusicInfoExtractor` will take care of acquisition, reduction and storage.

Core graphics

DiskPlay uses the *Core Graphics* to draw waveforms. It is a C-based API that provides simple 2D rendering. Since waveforms are usually made up of paths, 2D rendering is sufficient. Additionally, *Core Graphics*-objects are faster than their *Cocoa* equivalents.

Performance versus detail

Waveforms can provide different levels of detail. A highly structured waveform will take considerably more time to render than a low detail output, since the paths will need more nodes. The current implementation uses 400 samples per second, offering more than enough detail for the DJs. Since waveforms are constructed by linking edges together, the results can be pixelated. The waveform is using `CGMutablePaths` to create a mask for the drawing operation. Quartz paths provide anti-aliasing which will produce a nice visual output.

Create paths with a sliding window

Paths are created step by step by walking through a `NSMutableArray`. A sliding window is moved over the array, examining 1.8 seconds of waveform samples. Every sample is converted from a `NSNumber` into a 32-bit float

Figure 6.11: The baseline of a horizontal (left) and circular (right) waveform with displacement vectors

and scaled to fit into the waveform's display range.

Create a horizontal waveform

DiskPlay also features a horizontal waveform (see figure 6.10 - right). It consists of two paths using the same baseline. The top path is created by mapping sample values to 720 points (400 samplesPerSecond $*$ 1.8 seconds) on the baseline. To get the bottom part of the waveform, the upper part is mirrored along the baseline using `CGAffineTransform`. These paths are then chained together and clipped to create a mask for the waveform. To fill the resulting area, `CGContextDrawLinearGradient` is called to draw a linear gradient.

Precomputation for circular waveforms

To create a circular waveform, some precomputation needs to be done. There are two problems with this kind of visualization: The baseline is warped to a circle and there is a different displacement vector for every sample point (see figure 6.11). To enable a smooth visualization, the baseline and the displacement vectors need be precomputed and stored. Additionally, they need to be recomputed when window size changes to guarantee the same quality; a simple resizing operation will not suffice since it produces artifacts.

Sample a circle and save vector to the center

Just as the horizontal waveform, the circular waveform uses 400 samples per second. To get the X- and Y-coordinates of the individual locations on the new baseline, a circle is sampled with respect to the current `uiScaleFactor` and radius. For every sample, the vector, pointing to the center of the circle, is saved in an additional array.

Add data points, displace and draw

The actual waveform is drawn by moving the current point of the path to the current sample point on the baseline.

Next, it is moved along its displacement vector according to the corresponding waveform sample.The path can not be mirrored anymore. A second path has to be created to add the bottom part of the waveform. It is created in the same way as the top part, but the points are moved in the opposite direction of the displacement vector. The circular waveform is then drawn analogously to the horizontal waveform: The path creates a mask which is filled with a circular gradient.

MusicInfoExtractor

The `MusicInfoExtractor`-class takes care of the first three steps of the waveform implementation: Acquisition, reduction and storage. Whenever a new song path is received, the `MusicInfoExtractor` is called to analyze the song and provide the information to the `SelectionView`.

MusicInfoExtractor - Acquisition

Read audio file, create PCM, store in buffer

To analyze data of the audio files, the `MusicInfoExtractor` uses *ExtAudioFile* (Extended Audio File Services) which is part of Apple's *AudioToolbox* framework. It is able to open and decompress several audio file formats. Before the audio is read into a buffer, the PCM (pulse-code modulation) read format has to be specified. Most of the settings can be fetched from the audio file itself, just like the number of channels. Most MP3-files are sampled at 44.1 kHz, so the `MusicInfoExtractor` will walk through the complete audio file creating one 32 bit float per sampling point.

MusicInfoExtractor - Reduction

Reduce to preserve memory

After the raw PCM data has been acquired, it needs to be reduced. First of all, keeping the complete data set would take up much space. With 44100 samples per channel per second and one 32 Bit float per sample, a five minute song

would require 100 MBytes of memory. Additionally, the waveform will not be displayed in such detail and therefore most of the data can be thrown away.

Find the maximum value inside the window

Before the actual reduction is done, one has to decide how to sample the raw data. Since the output has to be rather accurate, it is important not to miss beats or drops. DiskPlay is using two search windows to reduce the data to 400 samples per second. There is one big search window which will look at one second of raw data. A second smaller window is used to examine `#samplesPerSecond`-parts inside the bins. The `MusicInfoExtractor` is searching for the maximum value of the PCM. Choosing the largest value works well for capturing all important transitions.

MusicInfoExtractor - Storage

The collected and reduced data will be stored as `NSNumbers` inside a `NSMutableArray`. The array will be filled up with zeros up to the 15 minute mark to prevent the `SelectionView` from accessing an empty array when one deck is switched to a different song. Considering that a five minute song would have taken up over 100 MBytes of memory when saved as raw data, the sampled data will only use 2.7 MBytes for 15 minutes. After the downsampled data has been stored, the raw data will be deleted.

6.4.5 Serato Scratch Live Performance

Scratch Live clogs drawloop

The output of DiskPlay is stuttering when Scratch Live is running on the same machine. Figure 6.12 shows the rendering time per frame of a Quartz Composition when Scratch Live has been started. The output of the tested Quartz Composition is stuttering similar to DiskPlay. To make sure DiskPlay is not causing the laggy output itself, it was tested if this behavior was reproducible with other applications. *GLEssentials*, one of Apple's example projects using OpenGL, exhibited the same behavior as the Quartz Composition and DiskPlay when Scratch Live is running.

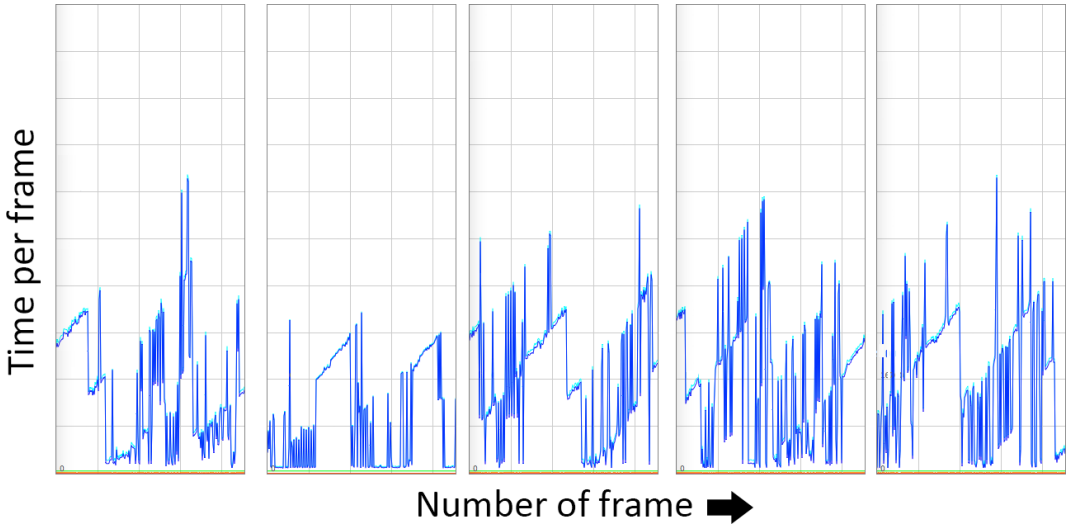


Figure 6.12: Performance analysis of Scratch Live - rendering time per frame (less is better) when Scratch Live is running

Alternative implementations were tested using OpenGL 3.0 and software rendering which lead to the same results.

Use DiskPlay on a separate machine

Since the DiskPlay application is able to receive information over the network, it can be moved to a second computer. This workaround will provide optimal performance but also require additional hardware.

Chapter 7

Evaluation

The following chapter will describe an online survey, a qualitative and a quantitative study that have been conducted. It will start off with a description of the target audience and how these users could be recruited. Next, the in-house usertest is presented. It is divided in a qualitative and quantitive study.The last segment will offer an overview of the findings and results of the evaluation.

7.1 Target User

Determine the target audience

To test DiskPlay, the participants should be picked from the target audience, which includes amateur and professional DJs. This study will concentrate on professional DJs, since they can provide more substantial feedback. In this study, a DJ is considered a professional when she is earning money with her profession and has at least one year of DJing experience. Additionally, they should be able to beatmatch manually without the use of technical aids (*auto-sync*). In conclusion, the participants should fulfill the following criteria:

- Professional background

- Basic manual beatmatching skills
- Basic knowledge of vinyl, CDJ systems or similar hardware controllers

Recruit participants in special forums

Recruiting this kind of professional DJ is hard. DJing is actually quite popular, but when compared to other hobbies or interests, it is quite hard to find DJs fulfilling the specified requirements. The best place to get in contact with professional DJs may be in dedicated DJ forums. Various threads have been opened in some of the most popular DJ forums to recruit participants for the in-house study and for taking a survey. Additionally, posters were put up locally to get in contact with the local DJ community.

7.2 Survey and Software Distribution

Use online surveys to reach more participants

The first step in evaluating DiskPlay was to set up an online survey to reach additional users and collect shallow data. Online surveys provide the best access to the user population since they are accessible worldwide. Lazar et al. [2010] states that there is evidence that people are being more honest when they are completing online surveys and are more willing to deliver bad news. The survey was set up using *Google Docs* [1], since it provides unlimited responses, a graphical response overview and is free of charge.

The survey should gather information on the following topics:

- Acceptability of systems similar to DiskPlay
- General usage statistics of DVSs
- General usage of visual and technical aids
- Is switching focus between control and information considered a problem?

[1] http://docs.google.com

7.2.1 Software Distribution

Make the prototype publicly available to gather more information

To give the participants a chance to test the system for a personal interview or to provide some extra information on DiskPlay, a software package was distributed. It included the complete software package and a short manual presenting the features and how to set up DiskPlay correctly. DJs were able to download DiskPlay and set it up at home if they had the required hard- and software. DiskPlay is capable of working with the demo versions of *Scratch Live* and *Serato Video*, so there is no need to purchase special software to take a closer look at the application. A dedicated page was included in the survey for participants that set the system up. The DJs that actively used DiskPlay were able to state if they felt that the system could help them. Participants that did not set up the system had the opportunity to explain why.

7.3 In-House Usertest

To get detailed information on DiskPlay, we conducted a lab study. It was designed to last at least one hour and give DJs the chance to test the DiskPlay system freely and under controlled conditions.

7.3.1 Experimental Design

Choose within-group desing

Since it is hard to find enough users, we chose a within-group design for the experiment. It allows for the isolation of individual differences and more samples to be taken (Lazar et al. [2010]). The DJs will be presented with several device setups in a random order and will be asked to repeat a certain task, therefore several measurements can be taken per user. It is important to minimize the learning effect when using the within-group design.

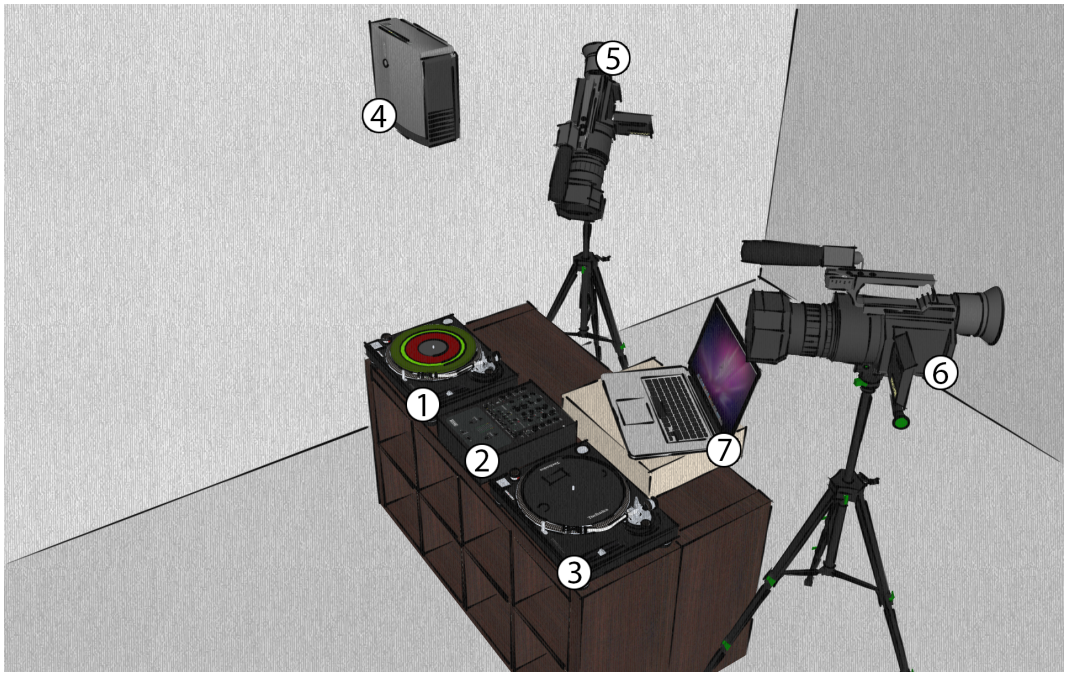


Figure 7.1: Hardware setup of the user test - 1: Turntable enhanced with DiskPlay — 2: DJ-mixer — 3: Standard turntable — 4: Projector — 5: Camera filming participants hands — 6: Camera filming participant — 7: Laptop running Scratch Live

7.3.2 Hardware Setup

A standard DJ setup and DiskPlay

Figure 7.1 illustrates the hardware setup used in the study. It is a standard two turntable DJ setup. There are two *Technics SL-1210 MK5* with timecode vinyls, a DJ-mixer (Gemini BPM-1000) in the center, a projector, two cameras and a laptop. One of the turntables is augmented with the DiskPlay application. Cameras have been set up to record the DJs body and his hands. Two *GoPro Hero 3*[2] were used since they provide recording in 1080p and are nonintrusive due to their size. The laptop was running *Scratch Live* in full screen.

7.3.3 Structure

The user test was structured in four main parts:

[2]http://gopro.com/hd-hero3-cameras

- Initial interview
- 20-25 minute introduction phase
- 20-30 minute quantitative study
- Final interview

During the tests, the participants were videotaped to analyze their actions later on. Additionally, there was an optional mixing session at the end where DJs could speak freely and play with the system without being videotaped.

Minimize learning effect by adding an introduction phase

None of the participants has ever worked with DiskPlay. To dampen the learning effect towards the new system, a short introduction was presented. Otherwise, the learning effect could lead to bad measurements when the participants gradually get better with the test setup. Although this can never be prevented completely, the learning effect has the most impact when users start off with a new device or system and will flatten over time.

Introduction phase - procedure

First of all the system is shown to the participant and the main features are explained. In the introduction phase, the left turntable was always projected with DiskPlay, the right turntable was just playing a standard timecode vinyl. DJs could start to mix with the system for 20 minutes, giving them the opportunity to play tracks of their own choice. Two songs had to be played, since they should be mixed in the quantitative study. By this, the DJs were able to familiarize themselves with the tracks. During the introduction phase participants could ask questions and comment on the system.

Uncontrollable variables

Although the experiment is conducted in the lab, there are several uncontrollable variables. A DJ's experience with beatmatching and turntables can take substantial influence on the time she needs to line up beat and phase. Nevertheless, an evaluation can be done, since all tests include the same beatmatching task with turntables. Because the setup is not symmetric, augmenting only one turntable with DiskPlay, it is important to make sure that this does not pose a problem to the participants. The participants

were specifically asked about this issue in the initial interview.

7.3.4 Initial Interview

Before the DJs could test DiskPlay, an initial structured interview was conducted. DJs were asked about the following topics:

- General DJ experience
- Experience with vinyl
- Experience with DVS
- Which software they use to perform
- Experience with Serato software
- Are they earning money with DJing
- Do they consider mixing from the left turntable to the right harder, than vice versa

7.3.5 Participants

Participant overview

Four male DJs agreed to take part in the user test. All of the participants were making money with DJing. One of them was a full-time DJ, another candidate was teaching DJing skills at a DJ school. They can be considered professional DJs since they play in front of an audience, can be booked for events. The participants' experience with DJing ranged from two up to 25 years and all of them were familiar with Serato software. One of the DJs was fairly new to digital vinyl systems, but knew how to use them since he was using a hardware controller with an interface similar to CDJ systems. The other three DJs had at least 1 year of DVS experience, ranging up to ten years. None of them was DJing with traditional vinyl. Because only one turntable was enhanced with DiskPlay, it was important to ensure that none

of the participants had difficulties with mixing from a specific turntable to the other. All DJs stated, that they do not notice a difference when mixing from the left to the right turntable or vice versa. None of the DJs considered himself a scratch DJ, which restricts this study to Mix DJs.

7.3.6 Qualitative Study

Observe interaction when synchronizing

First of all, the qualitative study was targeting interaction techniques when beatmatching. It was focused on how the DJs manipulate the vinyl and the turntable to align the two songs. It is important to know how they use their hand and where it is placed on the record or the turntable. The results can be used to construct new hardware prototypes or devices for DJs.

Gather information on focus switches

Secondly the number of focus switches when using DiskPlay and a traditional DVS setup are monitored. One of the cameras can help with the evaluation of where the participant is looking and how often he has to switch between computer screen and turntable.

Gather information on DiskPlay

Also information on DiskPlay was gathered. It was monitored if DJs seemed to have problems with the visual output, latency or the widgets. Not only were the DJs being watched throughout the whole lab session, but also the video recording was evaluated later on. We took notes when DJs had questions to DiskPlay or the setup and looked for situations when they had to correct their actions. The chosen thresholds for smoothing and displaying visual cues on the record needed to match the participants expectations and capabilities.

7.3.7 Quantitative Study

The quantitative study featured a dedicated mixing task where DJs hat to create a smooth transition between two songs and then fade into the incoming song. DJs were told to inform the instructor when the songs were matched.

Defining independent and dependent variables

The independent variables are the songs that should be beatmatched and mixed and the system setup that is used. The dependent variable for this test is the task completion time of the DJ. It is important to know if the use of a different DJ setups can influence the time a DJ takes to beatmatch two songs and create a transition. If the task completion time is lower with a certain setup, this can suggest that a DJ can work more efficiently with a certain system.

Experimental Setup

Three test scenarios in a random order

Three setups were being tested in the third phase. This included mixing to a traditional vinyl, a timecode vinyl and a timecode vinyl enhanced with DiskPlay. The test setups were picked in a random order. The right turntable was always playing the outgoing song while the left deck was playing the incoming song.

Use the same songs in every scenario

DJs had to complete the beatmatching task with the same songs in every test scenario. Songs were preselected to be able to test with a digital copy but also a vinyl pressing. Additionally, using the same songs guarantees the same difficulty for the beatmatching task. If songs were picked in a random order, one song could be easier to match to another and therefore take influence on the task completion time independently of the system that is being used.

Procedure

After the introduction phase a random system was picked. Song 1 was added to the right deck, song 2 was added to the left deck. Next, both turntables were started so they would be spinning when the DJ picks up the needle arm. The time was clocked from the moment when the DJ was picking up the needle arm until he told the instructor that the beatmatch was completed. In the last step the DJ had to prove that the beatmatch was achieved by fading in the new song routing the output through the speakers. The instructor can confirm if the DJ had indeed created a smooth transition since by listening to the result. In the second step

the DJ had to mix from song 2 to song 1. The presented process is repeated, with song 2 in the right deck and song 1 in the left deck. After the tasks had been completed, another system was randomly picked and the same task had to accomplished.

7.3.8 Post-Test Interview

Finally a semi-structured post-test interview was conducted. DJs were asked about the following topics:

- What did you consider helpful/unhelpful?
- Would you add/remove features?
- Did you notice the latency of the system and did it bother you?
- Anything else they want to add

7.4 Results

The results of the evaluation are presented in three steps, starting with the survey. Next findings of the qualitative study will be described and illustrated. Finally the results of the quantitative study are presented.

7.4.1 Results - Survey

A diverse user group

26 DJs volunteered to take part in the online survey. The experience of the DJs ranged from two up to 25 years. Most of them had used a DVS, some of them even used this kind of system for up to nine years. At least 57% of the participants were DJing in front of an audience. When asked for the software that they were using, there were mainly two factions: They either use Scratch Live by Serato or Traktor by Native Instruments. Only two DJs used VirtualDJ, three

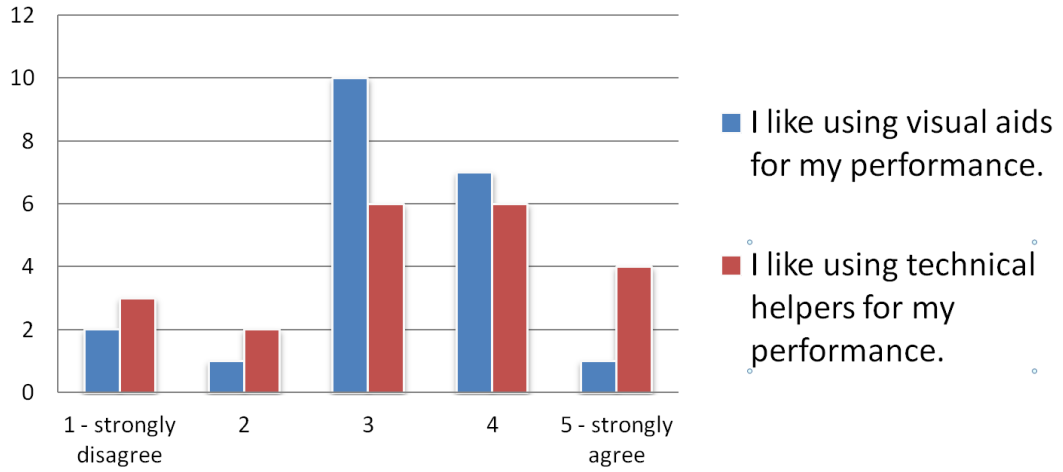


Figure 7.2: Results when asked for the use of visual and technical helpers

others did not specify which software they were currently using.

When DJs were asked about their own use of technical and visual aids, only a small number of participants completely refused to use any of them (see figure 7.2). Most of the DJs accept the additional features that companies provide. With a mean of 3.28 DJs tend to like technical helpers but a standard deviation of 1.3 shows that the participants often disagree on this topic. Visual aids are seen less controversial. The mean is 3.19 and the standard deviation is 0.98. DJs slightly favor visual aids and agree on this topic.

Although none of the lab-study participants had any difficulties with mixing from the one turntable to the other, this seems to be different with the survey candidates. With a mean of 2.4 the participants stated that most of them have no problem with this but the standard deviation of 1.42 shows that there are big differences among the participants (see figure 7.3 - blue). The test setup could have been problematic for them and would have to be rearranged accordingly.

When being asked about In-track navigation with traditional vinyl and a DVS (see figure 7.3 - red), the participants tend to favor the DVS (mean: 2.6). This suggests that the visual aids that DVS solutions provide can substitute some of

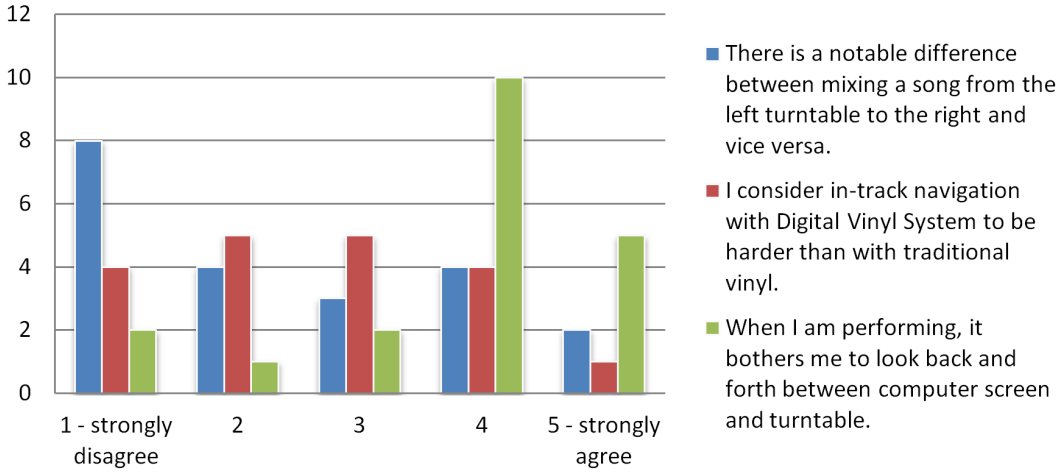


Figure 7.3: Results when asked for problems with DVS and the setup

the lost features. Only one DJ noted that he strongly agrees that it is harder to navigate with timecode vinyls.

Evidence that focus switching is problematic

One of the main concerns of DiskPlay is the separation of control and information through generic timecode vinyls. A mean of 3.75 shows clearly that most if the participants are bothered by the fact that they have to switch focus between the turntable and the computer screen (see figure 7.3 - green). This suggests that there is a real problem with digital vinyl systems and that users care about this topic.

Most DJs would feel comfortable to perform with DiskPlay

In the third part of the survey, DJs were asked about DiskPlay and if such a system would be acceptable for them. When being asked if they would feel comfortable to perform with a system similar to DiskPlay, most of the DJs seemed to be positive (see figure 7.4 - blue). With a mean of 3.89 and a standard deviation of 0.87 the DJs clearly voted in favor of DiskPlay. Only one of the participants would feel slightly uncomfortable.

Inconclusive if these systems are lowering the bar for DJs

When it comes to the visual help that DiskPlay provides and if it would lower the bar for the common DJ, the results are inconclusive, but showing a slight tendency in favor of towards DiskPlay (see figure 7.4 - red). Considering that most DJs train hard to improve themselves and acquire a certain set of skills, it seems plausible that some of them consider too much visual help as counterproductive.

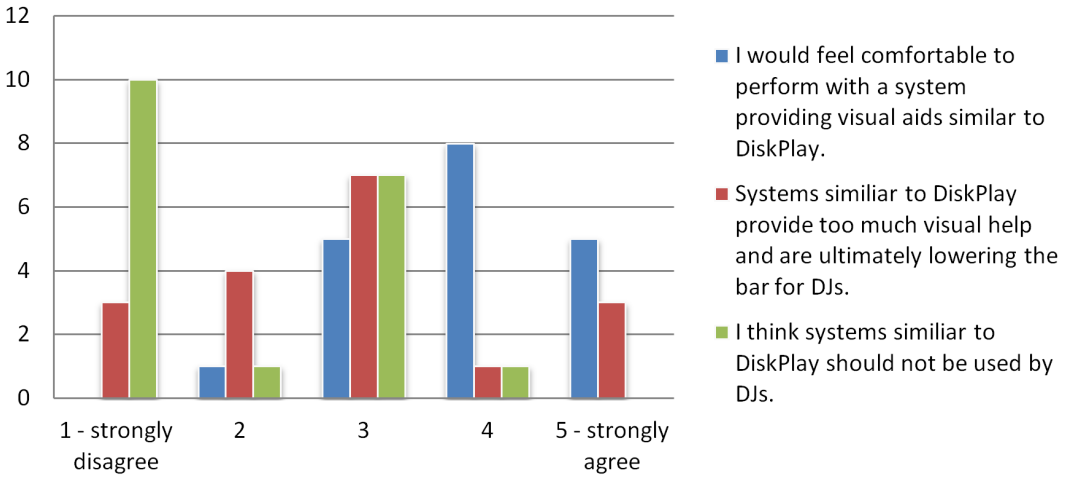


Figure 7.4: Results for DiskPlay's acceptability

Inconclusive if these systems are lowering the bar for DJs

A mean of 2.83 and a standard deviation of 2.94 show that some of the participants see the danger of lowering the bar for DJs and would not necessary use DiskPlay themselves, most of them are open minded when it comes to DJs that use such a system (see figure 7.4 - green). There is a large group (mean: 1.95 - standard deviation: 1.08) that strongly states that DJs should be able to use similar systems.

Only two of the participants did set up the DiskPlay system to take a closer look at the features. DJs were able to state why they did not set up DiskPlay. Most DJs (54 %) replied that they did not have the required hardware. 13% argued that the setup is too complicated, while 17% stated that it is too time consuming.

Acceptance for DiskPlay

In conclusion, there would be a user base for a final system like DiskPlay. DJs seem to be open minded when it comes to new additions and concepts for DJing. The use of technical and visual helpers seems to be acceptable for the DJs. Although Lazar et al. [2010] suggests that there must be 30 participants as a baseline minimum, the 26 volunteers could provide some insight into the thoughts of a modern DJ.

7.4.2 Results - Qualitative Study

DJs were observed during the whole time while they were mixing. The DJs got used to the new DiskPlay very quickly. All of the participants had worked with Serato software before, they had access to the features that they are used to additionally to DiskPlay.

Observational Findings - Features

Track visualization as high level navigation aid

The track visualization was received very well. Since it is a straightforward approach, participants immediately understood how to use it. All of them started right off by using it to navigate to the track start. Because it is only a coarse visual aid, most of them were unable to hit the exact start of the track. The track visualization offers a high level visual cue for navigation.

Cuepoint orbits as high level navigational aid

Some of the preselected songs had prepared cuepoints. After the presentation DJs tried to test if these were exactly where they were displayed but none of them was able to hit the exact groove of the cuepoint. This came to no surprise, since Lauten [2011] described the same problem with his implementation. The cuepoint orbits are used as a high level navigational tool, just as the track visualization.

Cuepoint progressbar as a second level navigational aid

The cuepoint progressbar was implemented to give users an additional tool to find cuepoints. All DJs managed to hit the cuepoint close enough that the cuepoint progress bar was displayed. This shows that the chosen threshold of eight seconds (see chapter 5.2.3 “Cuepoint Progressbar”), was clearly large enough for the participants. Only DJ2 dropped the needle once outside the threshold. After seeing the progressbar, all DJs were able to find the cuepoint very quickly by spinning the record in the right direction. But only two DJs actively tried to set up cuepoints to check out the recognition and the display on the record. Besides that cuepoints were not used in the study.

Waveform as low level navigational aid

The waveform was utilized by all DJs. They used it to cue up beats and especially to find the start of the song. At first,

some of the DJs still relied on the waveform presented by Scratch Live, but this changed once the participants familiarized themselves with DiskPlay and started trusting the waveform. It was mainly used as a high detail navigational tool. DJ3 and DJ4 additionally used it to pinpoint the exact beat when navigating to a cuepoint. Although one of the participants stated that he does not like to use visual aids, he started using the waveform actively after a short while.

Latency posed only a small problem

Although the latency of the visualization was clearly visible for the participants, only DJ4 seemed to be slightly irritated. He often scratched back and forth at the start of the song, looking at the waveform, trying to get a feel for the latency of DiskPlay and shook his head several times when he could not hit the beat using the waveform visualization. The waveform was always lagging behind during the scratching motion, leaving DJ4 to trust his hearing to find the exact beat.

Observational Findings - Interaction

Evalueate interaction techniques

One of the main objectives of the qualitative study was to identify how DJs synchronize the songs with a turntable. It is important to know how DJs interact with turntable and which parts they use to interact with it. One of the cameras was recording the hands of the participants and provided four hours of video recordings that were evaluated. We concentrated on the direct interaction with the platter and record. Therefore the needle arm and the pitch slider are not examined.

Coarse navigation is usually done with the needle arm. The speed is then matched by using the pitch slider. To keep the songs synchronous and navigate short distances DJs make us of the record, platter and motor shaft. Figure 7.5 provides an overview of the techniques that were identified throughout the study.

Navigation through rotation with two fingers

Figure 7.5 (1) illustrates which technique the DJs used to navigate to a certain position. Two fingers are placed on the record and the whole platter is rotated. The faster a DJ

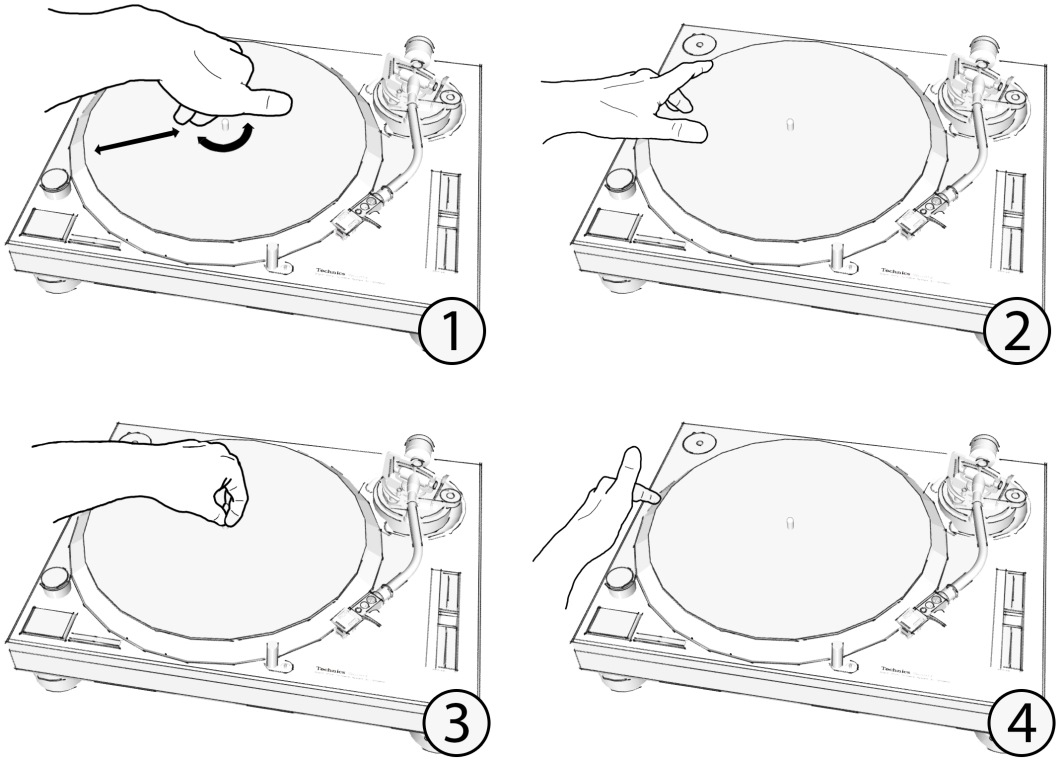


Figure 7.5: Different interaction techniques with the record and turntable

wants to spin the record, the more likely he is positioning his fingers near the center. This allows for a faster rotation without having to move the whole arm; by rotating the wrist the record is spun. When the participants approached the point they were looking for, the hand slowly moved to the outer regions of the record. The whole arm has to be used to rotate the record and allows for a more precise movement and navigation.

Accelerate and brake to keep in sync

Mainly, the interaction focuses on accelerating or breaking the record to keep it in sync with the outgoing song. Since a DJ can never completely line up the speed of two songs, constant corrections are crucial. Three different positions on the turntable have been used by the participants for this purpose.

Stopping and pushing from the top

Figure 7.5 (2) shows a hand touching the record with the middle and ring finger. The participants were touching the

record using both fingers to stop it for a short amount of time to get the phase of the record in sync again. Additionally, some of them applied a gentle push into the playing direction if the incoming song needed to catch up to the beat.

Rotating the shaft

Figure 7.5 (3) illustrates a participant grabbing the motor shaft in the center of the record. If it grabbed firmly, the platter can be slowed down or accelerated slightly, for as long as the DJ exercises a rotational force with her wrist and fingers.

Tap or push the platter or record from the side

The last figure (see figure 7.5- 4) depicts the hand of a participant which touches the platter from the side. To slow the incoming track down, the DJ puts her finger on the platter. If the song needs to catch up, the platter is accelerated by pushing it along its playing direction. While some DJs only touched the platter in the study, others sometimes touched the record to slow it down.

Observational Findings - Focus Switches

Amount of focus switches varies heavily

The amount of focus switches that could be observed varied considerably between DJs and sessions. Occasionally participants had to switch 15 times between turntable and monitor, when sometimes they were looking at one device for a long time. This behavior could be observed with and without DiskPlay. Often the DJs just let their eyes wander from monitor to the turntable and around the room. They did not necessarily seem to focus on a certain object. When mixing with traditional vinyl, the monitor was still displaying *Scratch Live*. DJ2 and DJ4 were observed looking at *Scratch Live* several times during their traditional vinyl mixing session.

During the mix-tasks in the third phase, DJ2 switched his focus 14 times with the first track and 5 times with the second song when he was using DiskPlay. Similar behavior could be observed when he was using the standard DVS setup. DJ1 and DJ4 looked at the turntable and the monitor for roughly an equivalent of time time. DJ4 exhibited even

considerably less focus switches without DiskPlay.

All of the DJ utilized the waveform presented on the record when DiskPlay was running. Still, they looked back and forth between turntable and monitor. No concrete evidence could be found that DiskPlay was able to reduce the amount of focus switches between turntable.

No concrete evidence for reduction of focus switches

7.4.3 Results - Quantitative Study

The quantitative study was split in two parts. Although it was planned to let DJs beatmatch the same songs, DJ1 complained that the chosen songs were indeed mixable but that it would be very hard. Considering that he has 25 years of experience, the songs were changed after DJ1 finished the quantitative study. Results of DJ1 are treated separately. Figure 7.6 illustrates the task completion time for all DJs with respect to the system that was used. Since every DJ had to mix two songs with every system, the results were added and divided by two to visualize the average time they took to complete the task. The results vary largely from one DJ to the other.

DJ1 showed better performance, the more visual helpers were added to the system. While he took the longest time when mixing traditional vinyl, he was significantly faster with DiskPlay. Using the DVS, he was slightly faster than with the traditional setup.

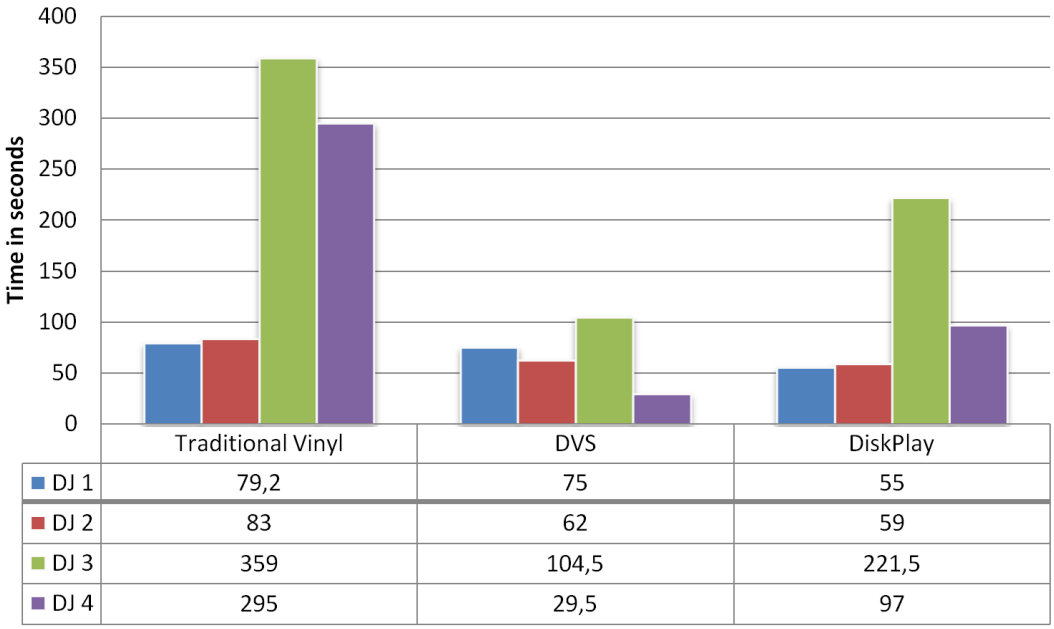
DJ1 faster with added visual help

DJ3 and DJ4 took very long to complete the task. DJ3 even had to reset the turntable containing the outgoing song to complete the mixing task. When it comes to DiskPlay and a DVS, results are mixed. Only DJ2 took less time with the DiskPlay system. DJ3 and DJ4 were considerably faster when they used the standard DVS.

Mixed results for DJ2, DJ3 and DJ4

The thing that stands out the most is that traditional vinyl showed the poorest performance. The findings coincide with the results of Lopes et al.. This suggests that the DVS and DiskPlay did actually provide additional help to the DJs. Although some DJs were actually faster with the tra-

Traditional turntables poor performance, DVS and DiskPlay with mixed results



	Traditional Vinyl	DVS	DiskPlay
DJ 1	79,2	75	55
DJ 2	83	62	59
DJ 3	359	104,5	221,5
DJ 4	295	29,5	97

Figure 7.6: Average task completion time in seconds for mixing task in the quantitative study

ditional DVS, some were also faster with DiskPlay. Because only a small number of volunteers could be found, it is hard to come to a conclusion if DiskPlay can enhance the performance of the mixing task.

7.4.4 Results - Post Test Interview and DJ Comments

In the post test interview DJs were asked about the features of DiskPlay, what they were missing and what should be removed. They were able to speak freely after the initial question phase. Additionally, DJs were encouraged to talk and mention anything that comes to their minds during the test.

Latency only a problem for DJ4

Only DJ3 and DJ4 did mention the latency of DiskPlay. DJ3 stated: *"I could see that there is some obvious latency, but that did not bother me at all"*. Because DJ4 made active use of a scratching motion when starting the incoming song, he was criticizing the waveform as too slow and that it fell

behind sometimes. The lag of the DiskPlay prevents the waveform visualization from catching up to the current position when the record is moved back and forth rapidly. It will sway between the starting and stopping position of the scratch gesture, never reaching one of the two if the record is not stopped for a short time. DJ1 and DJ2 were asked if they noticed the latency. Both replied that they observed it sometimes but did not care.

Hardware setup is too complicated

Although all participants were told that the test setup is a prototype, all of them mentioned that it would be very complicated to set it up. None of the participants were willing to carry a projector around. *"Maybe this would be interesting if it was preinstalled in a club somewhere."*

Focus switches were considered a problem

Three of the four DJs were bothered by the focus switches that had to be done when perform with a DVS. DJ2 stated: *"It is about time that someone does something about this. It has been bothering me since I bought my DVS"*. DJ1 mentioned several times that he does not like to look back and forth between monitor and turntable. He continued to add that he would really like the idea to *"have the visualization where he is working"*. When DJ4 was asked if he would consider focus switching a problem he stated that he would not care. While DJ1 was performing in the introduction phase he caught himself looking at the screen even if he did not need to. He added: *"Although I could easily use the waveform on the record, I am still looking at the waveform of Scratch Live"*. DJ2 mentioned something similar: *"I think it's a habit that I continue looking at the monitor"*.

There are still missing features

When asked for what they missed when they were playing, three out of four DJs mentioned the comparative beatmatching tool by Scratch Live. When asked if they utilize it when they are performing, all four confirmed that it is a very important tool. DJ2 even mixed several songs visually by looking at the screen without using the headphones. Just before creating the transition, he checked the headphones if the beatmatch was completed. Two DJs wanted a BPM display to be added to the visualization, DJ1 asked for an additional absolute time display. DJ1 additionally asked for an option to separate the waveform into low, mid and high frequencies to be able see the beat in a "crammed" waveform

. This can happen easily whenever a song is very loud and many different instruments or samples are being played. DJs 2 to 4 asked for a mood representation on the vinyl to help them navigate to certain positions.

DJ comments on the implemented features

All of the DJs liked the song visualization, including artist and title. One DJ mentioned that it would give him a good overview of the song and how long the track was still playing. The song ending alarm was considered a valuable addition. The waveform display was also received very well. All DJs considered it to be an excellent addition to the visual output. This correlates with the observation described in 7.4.2 "Observational Findings - Features", showing all DJs actively using the waveform output on the record. DJ1 stated the "*waveform is very important*" to him and he would consider it to be the most valuable part of the DiskPlay visualization. DJ1 and DJ4 additionally stated that it would help them to find the first beat of the track. DJ3 said: "*I did not expect the waveform to be that precise, it works great as an indicator to find the correct beat*". Although none of the participants were actively using cuepoints during the free mixing session, all of them liked the idea. DJ2 stated that he would like to be able mark certain samples inside a track with a particular color, which then should be displayed as a long line following the groove.

7.4.5 Discussion

The survey and the interviews with the participants show that there is not only acceptance for a system similar to DiskPlay but DJs would also like to perform with it. DJs would be willing to buy such a system. The use of visual aids was ok for most DJs, the use of technical helpers still divides some of the DJ community.

The presented DiskPlay application was received very well by the invited DJs. The added functionality seems to improve the DiskPlay experience. The cuepoint progressbar and waveform could successfully solve the problem with coarse navigation of the cuepoints due to resolution restrictions. Still DJs keep asking for a BPM display on the record

and an absolute time display. The comparative beat aid of Scratch Live was used by three of four DJs. Since Scratch Live provides a visual tool for beatmatching, DJs tend to look at the computer screen to check on it. It could be a valuable addition for DiskPlay when a good location on the record could be found. The waveform was considered the most valuable addition by some of the participants.

Comparing the different systems proved to be very hard. First of all, the participants had different styles of DJing. Some depended more, some less on the visual feedback provided by Scratch Live. Most DJs are stuck in their habits and have difficulties to adjust to a new system. DJ3 stated beforehand that he does not like to use visual helpers. He ignored the screen most of the time. DJ2 stated that he "*loves the visual feedback of Scratch Live*". Although he switched his focus several time, he was mostly looking at *Scratch Live*, whether DiskPlay was enabled or turned off. DJ4 was also very fond of *Scratch Live* and exhibited similar behavior. What this shoes is that these DJs tend to stick to their habits and are displaying a behavior which can be connected to their statements. This became even more clear when DJ2 and DJ4 were watching the screen when they were performing with traditional vinyl. To get more precise results regarding task completion time when mixing, a significantly bigger study should be conducted. Not only would it require more participants, but additionally DJs should be invited several times. DJs need to get used to the new DiskPlay system. If the amount of focus switches should be reduced permanently, a long term or a case study should be conducted. Still some evidence could be found that traditional vinyl could be the least effective way to mix two songs, since it provides less visual feedback.

The qualitative study provided useful information regarding the interaction when synchronizing songs. Four locations on the vinyl have been identified which were used by the DJs to manipulate the platter and record. They can help to better understand which input capabilities Mix-DJs need and on which parts of the turntable they rely on. Additionally, this information could help to build a hardware prototype in the future. Considering that only actions of four participants were analyzed, other kinds of interaction

techniques could exist and more participants should be observed to get a more comprehensive results.

Chapter 8

Summary and future work

The last chapter will provide an overview of this thesis, summarizing the work that has been done and what was achieved. Afterwards, ideas and thoughts for future work are presented.

8.1 Summary and contributions

This thesis presented DiskPlay, a tool for DJs to bring control and information back together. Digital Vinyl Systems offer many benefits to the modern DJ and there is still room for improvement. DiskPlay actively grabs information from Scratch Live, processes the data and provides the output on the record, fusing together control and information. In the evaluation, basic interaction techniques of song synchronization with turntables were identified and the acceptance of the DiskPlay system was investigated. Professionals were invited to test the prototype and provide additional feedback on the implemented features.

Inner workings of a DVS and its problems

At first, the inner workings of a DVS are described. Timecode vinyls and CDs are used to feed a timecode to the software which manipulates the current song according to ab-

solute position and playback speed. The standard commercial setups provide extended visual aids and low latency, making them an interesting choice for many DJs. But modern DVS also introduced new problems, separating control and information.

Comparative turntable studies provided initial input

Two comparative turntable studies were analyzed to get an initial idea of what DiskPlay should look like and how to evaluate the final prototype. The last DiskPlay project offered some insight of what DJs would like to see when it is being projected onto the record and highlighted problems they had with system. Additionally, we took a closer look at scientific- and art-projects about turntables and DJing. These presented some interesting design choices for song visualization and interaction.

Implementation of different applications and plugins to provide feedback on the record

After defining the basic design rules, two prototypes have been implemented in this thesis. The first prototype used only Quartz Composer and was deemed to be unreliable. The final prototype consists of two applications and one Quartz Composer plugin for Scratch Live. The infoBroadcast pipes out information provided by Scratch Live. To get the cuepoint information from Scratch Live, a dedicated application was added. The Cue-Point-Feed tracks the cuepoints visually, using optical character recognition. Finally the DiskPlay application will produce the visual output. Both, the infoBroadcast and the Cue-Point-Feed, use multicast to send their information to the DiskPlay application. By this, the visual output is made independent from the host software, being able to display the information on every machine in the same local network.

Gather information on DiskPlay with an online survey

An online survey was set up to gather general information on DJs, their habits and preferences. The DiskPlay software package was made available free of charge. DJs were able to test the system if they had the required hardware and were willing to set it up. The results show that DiskPlay is an acceptable way of providing help to DJs and that the current setup including a projector is too complicated.

Lab study with professionals

A lab study was conducted to evaluate the DiskPlay system. Four professional DJs were invited to provide information and feedback in interviews, a qualitative- and a

quantitative study. A free mixing session and three controlled mixing tasks had to be completed by the participants. The feedback from the DJs was generally positive, criticizing mostly the complicated setup incorporating a projector. It could not be confirmed that DiskPlay reduces the amount of focus switches. The amount of focus switches that occurred while mixing to a standard DVS and a DiskPlay turntable depended heavily on the DJ and his habits. The mixing task provided evidence that suggests that traditional vinyls are difficult to beatmatch due to their lack of visual aids. Additionally, basic interacting techniques for song synchronization with turntables have been identified.

Contribution

This thesis contributes by showing that turntables enhanced with DiskPlay are acceptable for a DJ. It identified interaction techniques commonly used by mix-DJs. Additionally a software prototype was developed that is able to provide information on the record and can be used over the network, actively separating source software and output mechanism. Furthermore, the study provided evidence that beatmatching with additional visual aids can be done more easily.

8.2 Future work

8.2.1 Eliminate latency

Gain direct access to Scratch Lives' memory

One of the problems that DiskPlay had to overcome was the unsteady flow of information from Scratch Live. Instead of using Quartz Compositions and trust Serato Video with the data acquisition, it should be tried to gain access to the memory of Scratch Live. This could prove to be a reliable method of getting constant updates on song position, time and maybe cuepoints. Therefore the need of smoothing time could be eliminated, removing most of the system's latency. There would not be the need of optical character recognition to get cuepoint-timing information. As a result the cuepoint visualization could be more exact, offering pinpoint accuracy for markers on the record. Addition-

ally, eliminating the system's latency could make it more suitable even for scratch-DJs.

8.2.2 Additional Features

Add a BPM or beatmatching display

Some DJs asked for a BPM display. Adding a text display to the output could provide additional help, but would also add more clutter. A beatmatching visualization similar to the widget used in Scratch Live could help to see if the beats are actually in sync. It could be displayed on the edge of the record or the central sticker, rotating with the current song. If the current song's BPM is higher than the BPM of the other track, the widget could rotate a little slower than the waveform. The more the two songs are being synchronized, the more synchronous the waveform and the BPM matching display should rotate.

The mode switch for a song mood display

Adding a mood representation of the song proved to be an issue for DiskPlay. The record did not offer room for it, since it would have to compete with the standard waveform display. The song mood should be mapped to the record and be visible below the needle (see figure 5.5). A sensor on the tonearm could help by switching between two modes. When the needle is touching the record, the standard waveform display could be activated. Picking up the tonearm could switch to mood-mode, displaying a very compact waveform from the start of the timecode to its end and hiding the high detail waveform. The DJ would be able to drop the needle in the area of the song that she is looking for.

8.2.3 One Device - A New Kind of Turntable

Displays inside a turntable

The ultimate goal for the DiskPlay system should be the integration into a single device. A turntable that would be enhanced with an integrated display could be used. This would either require a circular display or an array of four screens built around the central motor shaft. The need for an external projector could be successfully eliminated.

Although there were other approaches incorporating big touchscreens (Lopes et al.), they lack the haptic feedback that real turntables provide. If a single device should be built, it is important to keep the turntable metaphor in mind. This includes the rotating platter, the needle arm and direct manipulation of both. To actually use a monitor with a turntable, it must be installed below the platter, putting a clear see-through platter on top.

Remove the record, use the platter to manipulate the music

Maybe the records could be completely replaced. Using an approach similar to Beamish et al. [2003b], only the platter could be manipulated. This would allow for a clear view onto the screen and would not require a clear vinyl to be use. If such an approach should be pursued, a replacement for the traditional needle arm has to be found. It could look similar and be motorized, moving inwards with the progression of music - just without an actual needle. Other ideas include a simple rotating knob which can be used to scroll inside the track. Both of these approaches would require an additional marker on the record that represents the current playback position.

Integrate a computer into a turntable

Since DiskPlay already features network functionalities, it could be used to do the output on a computer inside a turntable. The data input would be provided by a host computer running Scratch Live. Moreover, a *Raspberry Pi* could be used to display a videostream from a host computer which could contain the complete visualization.

Remove the laptop completely

A display inside the turntable could ultimately remove the need for a laptop. The turntable itself can be input and output device. It could feature a music library, setting dialogs and the DiskPlay visualization. Just like a *Pioneer CDJ2000* (see figure 1.2), a device could be created which integrates all important features.

8.2.4 Extended Long Term Study

Test with more participants in several sessions

To get a more refined view on the task completion time when beatmatching, an extended or long term study should be conducted. This includes testing with more par-

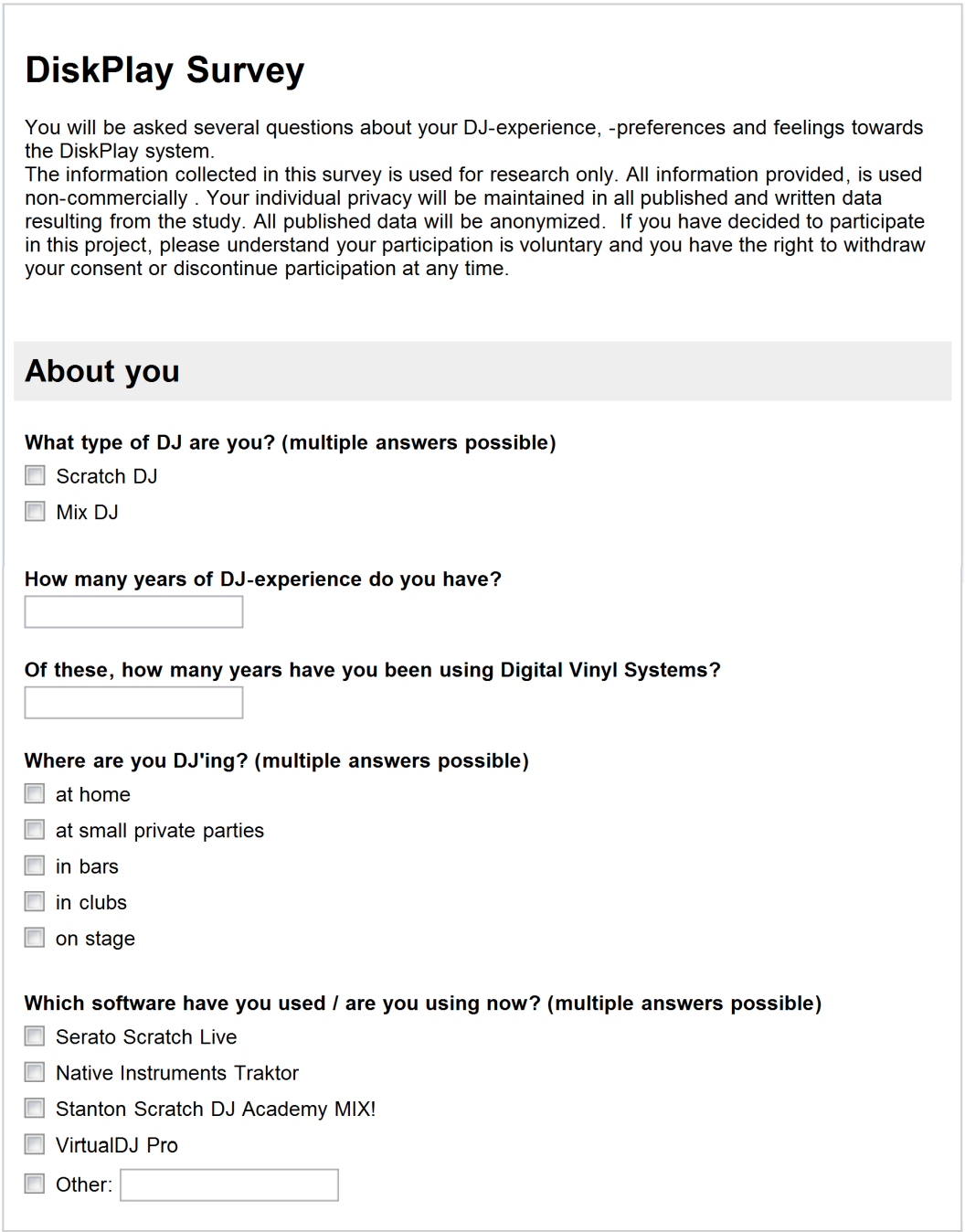
ticipants and for several sessions, to be able to get more concrete results. DJs are often stuck in their habits which makes it hard to draw conclusions in an one hour user test. The participants should be able to use the system for a certain amount of time to accustom themselves with the system and its features. By inviting DJs to several sessions, it could be determined if the participants would accept the turntable as the main visual output and if focus switches could be actively reduced.

Test with broad user group

Additionally, there should be a broad and diverse user group. The way a participant is DJing determines the way she is using the visual and technical aids. Scratch DJs could profit even more from a display on the record, which would allow them to find certain beats visually. Comments and feedback from Scratch DJs could provide an additional perspective.

Appendix A

Survey Overview and Results



DiskPlay Survey

You will be asked several questions about your DJ-experience, -preferences and feelings towards the DiskPlay system.
The information collected in this survey is used for research only. All information provided, is used non-commercially . Your individual privacy will be maintained in all published and written data resulting from the study. All published data will be anonymized. If you have decided to participate in this project, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time.

About you

What type of DJ are you? (multiple answers possible)

- ☐ Scratch DJ
- ☐ Mix DJ

How many years of DJ-experience do you have?

Of these, how many years have you been using Digital Vinyl Systems?

Where are you DJ'ing? (multiple answers possible)

- ☐ at home
- ☐ at small private parties
- ☐ in bars
- ☐ in clubs
- ☐ on stage

Which software have you used / are you using now? (multiple answers possible)

- ☐ Serato Scratch Live
- ☐ Native Instruments Traktor
- ☐ Stanton Scratch DJ Academy MIX!
- ☐ VirtualDJ Pro
- ☐ Other:

Figure A.1: Survey page 1

About DJ'ing and digital vinyl systems

Please read the following statements and choose if you agree or disagree.

I like using technical helpers (autosync, jump-to-cuepoint, ...) for my performance.

1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

I like using visual aids (waveform, BPM-display, ...) for my performance.

1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

When I am performing with a Digital Vinyl System, i use the following mode of operation for the vinyl:

- ○ Absolute Mode
- ○ Relative Mode
- ○ I don't use Digital Vinyl Systems.

There is a notable difference between mixing a song from the left turntable to the right and vice versa.

I feel more comfortable mixing from a certain side to the other.

1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

I consider in-track navigation with Digital Vinyl System to be harder than with traditional vinyl.

1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

When I am performing, it bothers me to look back and forth between computer screen and turntable.

For example: When you are searching for certain positions in a track, checking remaining song duration or finding beats by looking at the waveform.

1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

I regularly use cuepoints to help me find certain positions inside a track.

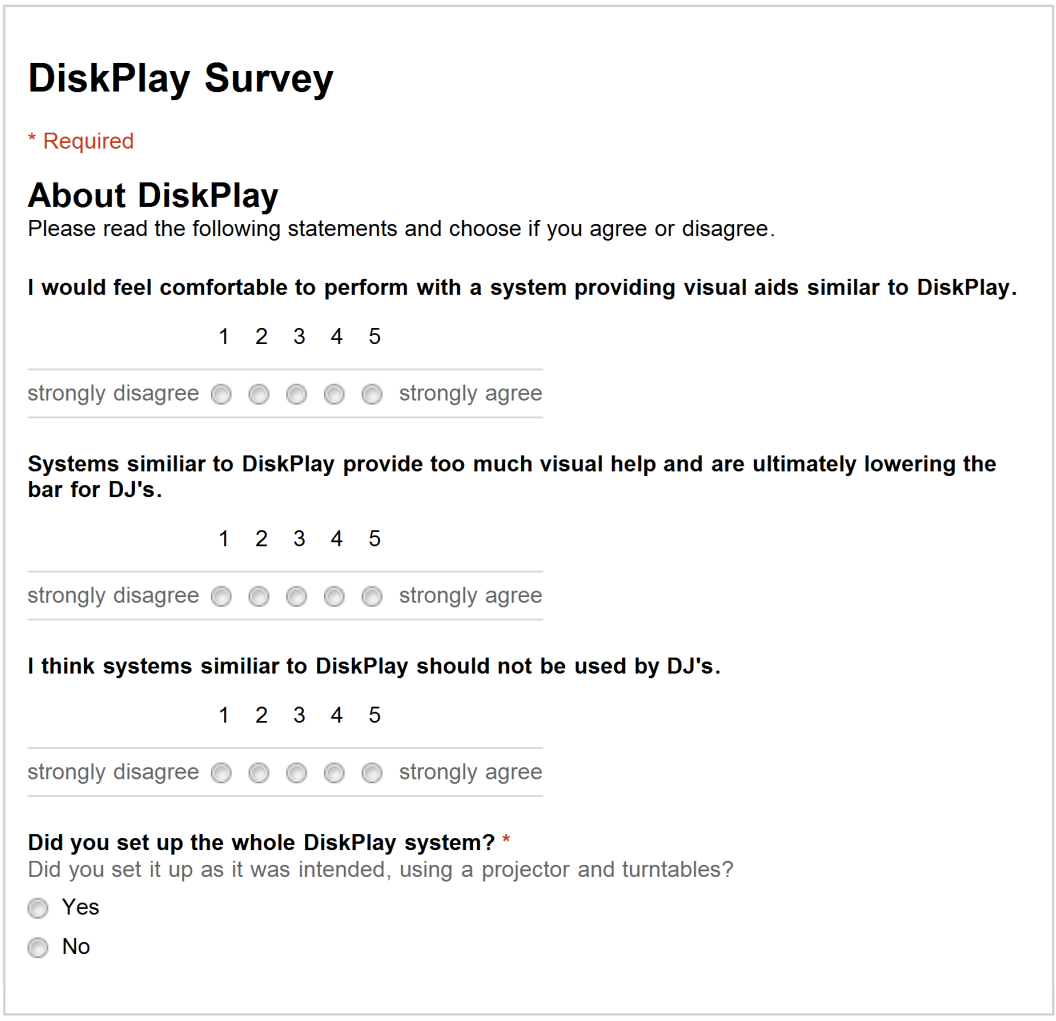
1 2 3 4 5

strongly disagree ○ ○ ○ ○ ○ strongly agree

The number of cuepoints i use per song is averaging at:

- ○ 0
- ○ 1-2
- ○ 3-4
- ○ 5 or more

Figure A.2: Survey page 2



DiskPlay Survey

* Required

About DiskPlay

Please read the following statements and choose if you agree or disagree.

I would feel comfortable to perform with a system providing visual aids similar to DiskPlay.

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Systems similiar to DiskPlay provide too much visual help and are ultimately lowering the bar for DJ's.

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

I think systems similiar to DiskPlay should not be used by DJ's.

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Did you set up the whole DiskPlay system? *

Did you set it up as it was intended, using a projector and turntables?

- ○ Yes
- ○ No

Figure A.3: Survey page 3

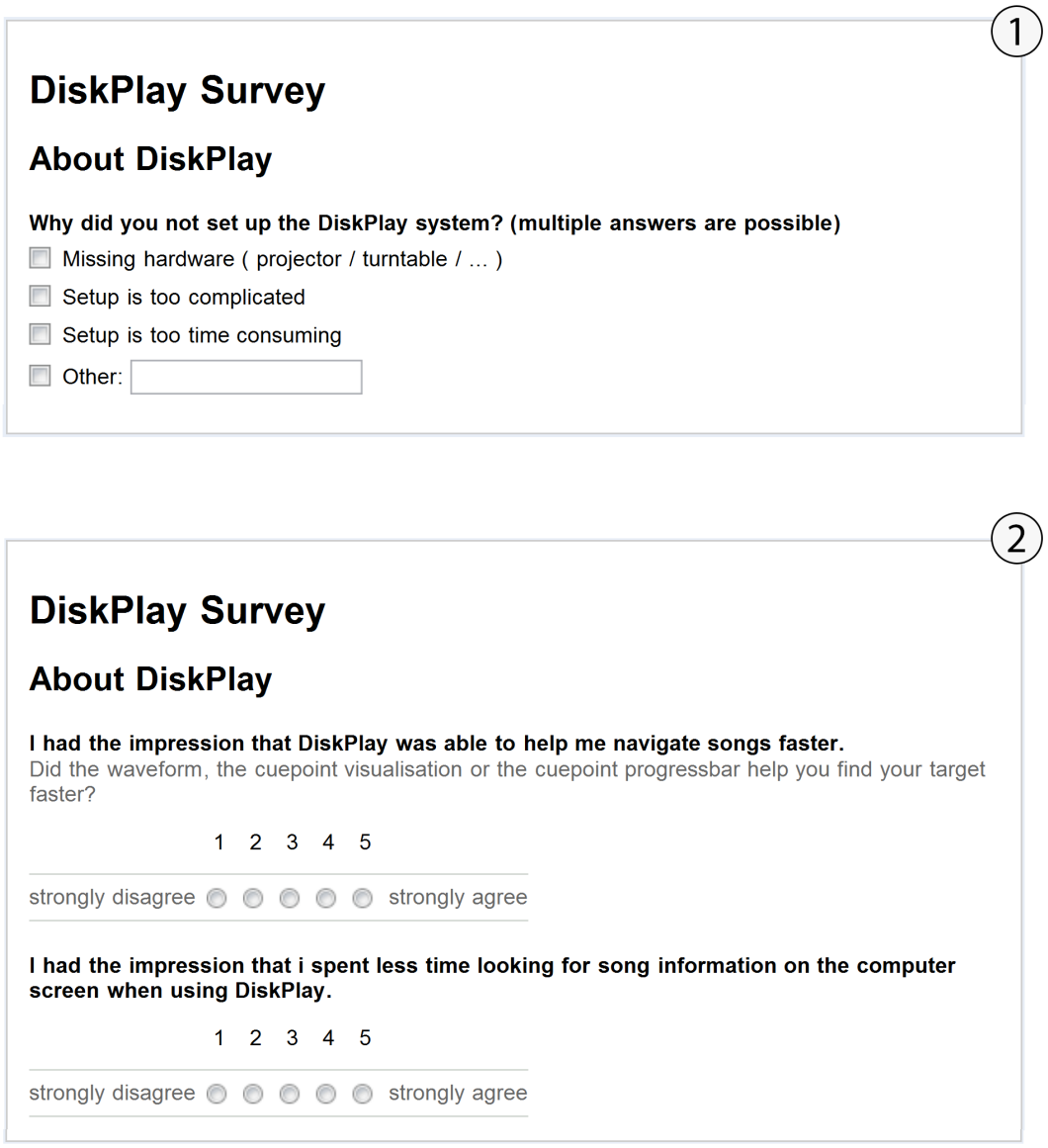
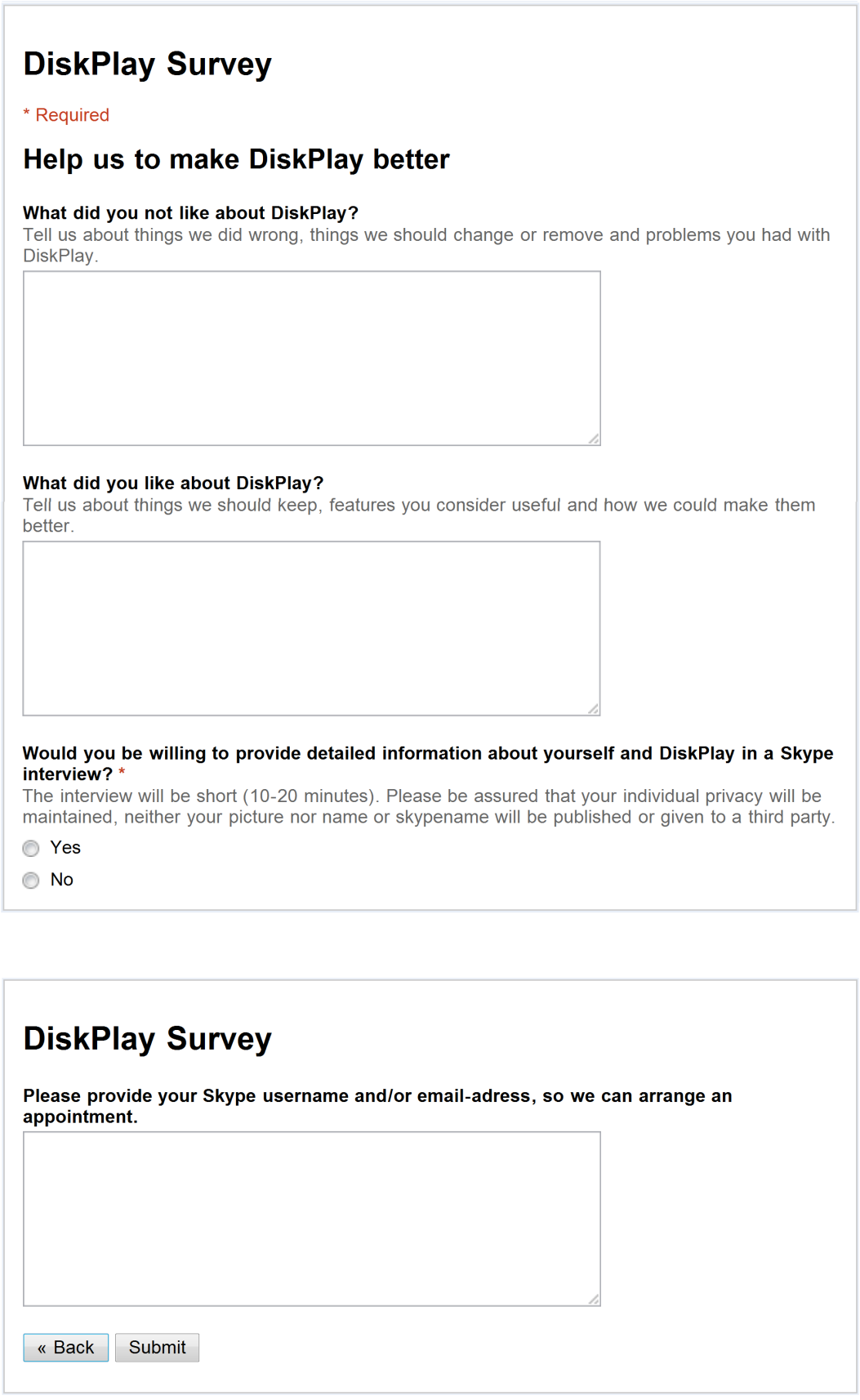


Figure A.4: Survey page 4 and 5



DiskPlay Survey

* Required

Help us to make DiskPlay better

What did you not like about DiskPlay?
Tell us about things we did wrong, things we should change or remove and problems you had with DiskPlay.

What did you like about DiskPlay?
Tell us about things we should keep, features you consider useful and how we could make them better.

Would you be willing to provide detailed information about yourself and DiskPlay in a Skype interview? *
The interview will be short (10-20 minutes). Please be assured that your individual privacy will be maintained, neither your picture nor name or skypename will be published or given to a third party.

Yes
No

DiskPlay Survey

Please provide your Skype username and/or email-adress, so we can arrange an appointment.

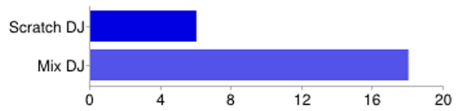
« Back Submit

Figure A.5: Survey page 6

Summary Publish analytics

About you

What type of DJ are you? (multiple answers possible)



Scratch DJ	6	25%
Mix DJ	18	75%

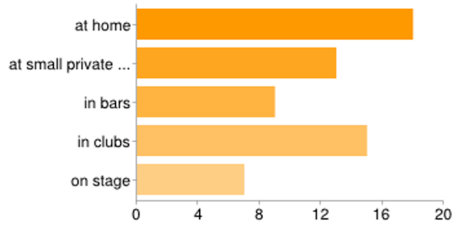
How many years of DJ-experience do you have?

15 5 15 9 5 13 7 13 25 2 8 15 6 10 years 4 5 2 11 13 3

Of these, how many years have you been using Digital Vinyl Systems?

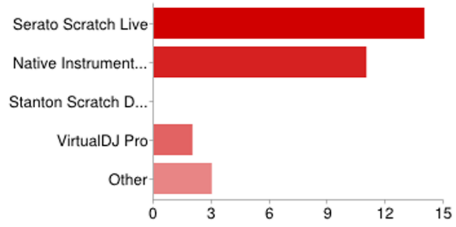
7 4 8 6 3 2 3 6 8-9 1,5 7,5 5 4 0 0 5 2 1 8 2

Where are you DJ'ing? (multiple answers possible)



at home	18	29%
at small private parties	13	21%
in bars	9	15%
in clubs	15	24%
on stage	7	11%

Which software have you used / are you using now? (multiple answers possible)



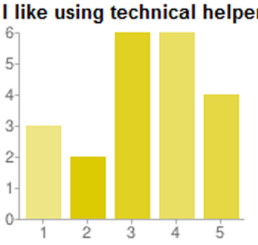
Serato Scratch Live	14	47%
Native Instruments Traktor	11	37%
Stanton Scratch DJ Academy MIX!	0	0%
VirtualDJ Pro	2	7%
Other	3	10%

Figure A.6: Survey-results page 1

About DJ'ing and digital vinyl systems

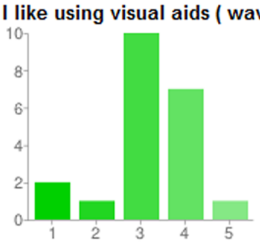
Please read the following statements and choose if you agree or disagree.

I like using technical helpers (autosync, jump-to-cuepoint, ...) for my performance.



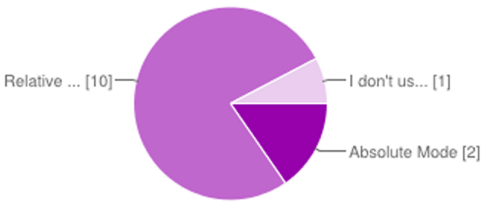
1	3	14%
2	2	10%
3	6	29%
4	6	29%
5	4	19%

I like using visual aids (waveform, BPM-display, ...) for my performance.



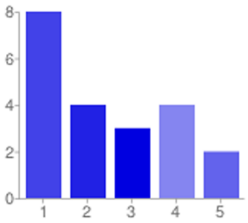
1	2	10%
2	1	5%
3	10	48%
4	7	33%
5	1	5%

When I am performing with a Digital Vinyl System, i use the following mode of operation for the vinyl:



Absolute Mode	2	15%
Relative Mode	10	77%
I don't use Digital Vinyl Systems.	1	8%

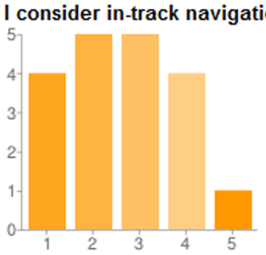
There is a notable difference between mixing a song from the left turntable to the right and vice versa.



1	8	38%
2	4	19%
3	3	14%
4	4	19%
5	2	10%

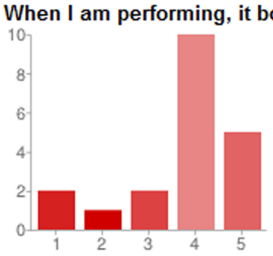
Figure A.7: Survey-results page 2

I consider in-track navigation with Digital Vinyl System to be harder than with traditional vinyl.



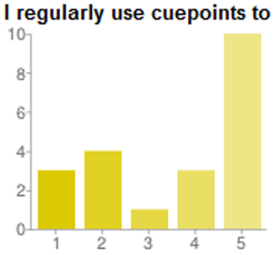
1	**4**	21%
2	**5**	26%
3	**5**	26%
4	**4**	21%
5	**1**	5%

When I am performing, it bothers me to look back and forth between computer screen and turntable.



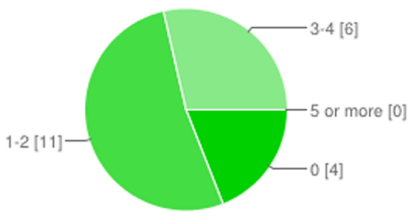
1	**2**	10%
2	**1**	5%
3	**2**	10%
4	**10**	50%
5	**5**	25%

I regularly use cuepoints to help me find certain positions inside a track.



1	**3**	14%
2	**4**	19%
3	**1**	5%
4	**3**	14%
5	**10**	48%

The number of cuepoints i use per song is averaging at:



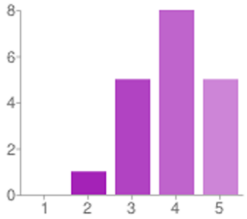
0	**4**	19%
1-2	**11**	52%
3-4	**6**	29%
5 or more	**0**	0%

Figure A.8: Survey-results page 3

About DiskPlay

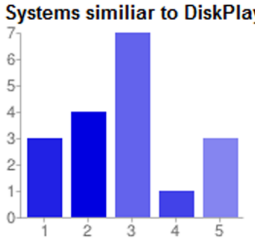
Please read the following statements and choose if you agree or disagree.

I would feel comfortable to perform with a system providing visual aids similar to DiskPlay.



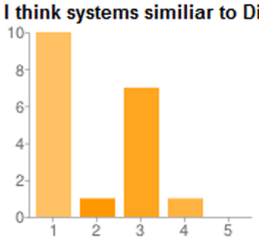
1	0	0%
2	1	5%
3	5	26%
4	8	42%
5	5	26%

Systems similiar to DiskPlay provide too much visual help and are ultimately lowering the bar for DJ's.



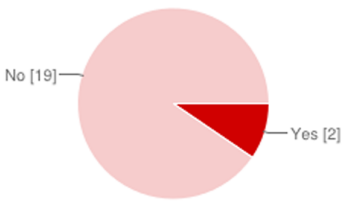
1	3	17%
2	4	22%
3	7	39%
4	1	6%
5	3	17%

I think systems similiar to DiskPlay should not be used by DJ's.



1	10	53%
2	1	5%
3	7	37%
4	1	5%
5	0	0%

Did you set up the whole DiskPlay system?

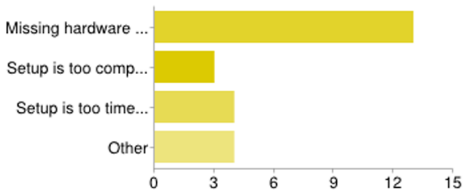


Yes	2	10%
No	19	90%

Figure A.9: Survey-results page 4

About DiskPlay

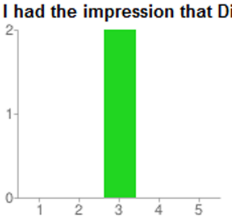
Why did you not set up the DiskPlay system? (multiple answers are possible)



Missing hardware (projector / turntable / ...)	13	54%
Setup is too complicated	3	13%
Setup is too time consuming	4	17%
Other	4	17%

About DiskPlay

I had the impression that DiskPlay was able to help me navigate songs faster.



1	0	0%
2	0	0%
3	2	100%
4	0	0%
5	0	0%

I had the impression that i spent less time looking for song information on the computer screen when using DiskPlay.

1	0	0%
2	0	0%
3	2	100%
4	0	0%
5	0	0%

Figure A.10: Survey-results page 5

Help us to make DiskPlay better

What did you not like about DiskPlay?

Well it's not something easily changed but the requirement for a projector makes it more of a novelty that most people would be unlikely to use. To be honest, I think it's a cool thing and I might try it out at some point, but I don't see it addressing a real need that exists.

latency (what I saw on the videos)

diese projektorsache ist zu komplex unflexibel für den harten Club und stage Einsatz, eignet sich eher für ne festinstallation im Club - aber tolle Idee! ich würde solche Anstrengungen aber eher nicht auf tts aufwenden sondern eher was mit nem richtigen Display, cdjs, Controller. da wäre sowas extrem hilfreich und liesse sich auch deutlich besser vermarkten.

What did you like about DiskPlay?

everything....perfect idea and this would help djs a lot.....keeep going with your work

it is nice to have a visualization of the remaining track length and the information about the artist and title currently played are very nice features as well. for those who are using queue points their visualization is on of the best time saving features i guess. the waveform feature might also help to find the perfect position in the track and improve skills to the next level!

Very cool proof of concept, and it could be fun to use.

chievly the idea

Idee ist wirklich top und durchdacht! thumbs up!

Would you be willing to provide detailed information about yourself and DiskPlay in a Skype interview?

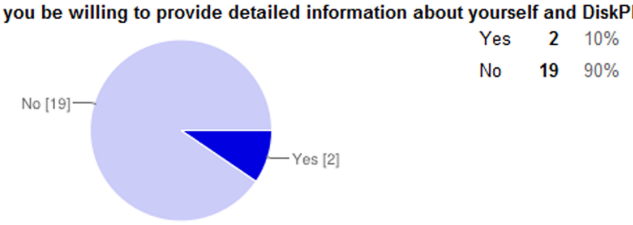


Figure A.11: Survey-results page 6

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