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Master Thesis

Bandwidth to Band Together

A Study on Approaches for Remote Music Collaboration

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Abstract

This thesis evaluates approaches of remote collaboration in a contextualised setting of traditional Digital Audio Workstations (DAWs) ability to facilitate collaboration, and contemporary solutions for Remote Music Collaboration Systems (RMCS). With a review of three approaches to remote collaboration, they have been evaluated by opportunities and constraints in a collaborative songwriting and mixing setting. By using a framework for categorizing DAWs utilization and usage, existing DAWs have been evaluated and contextualized with how they can transition into approaches for remote collaboration. The research has been conducted by examination of existing platforms, review of literature and previous research, personal experiences, and an experiment where approaches of remote music production have been tested with a following group interview. The results present an overview of contemporary solutions, possibilities and obstacles when conducting remote music production.

Acknowledgments

This master thesis is a continuation of my research internship together with the PLATFORM project [1] in the fall of 2022 where I wrote about categorization of DAWs based on features and functions into Amateur-, Artist- and Mix-Centric categories.

I would like to thanks my supervisors Emil Kraugerud and Yngvar Kjus that has helped me through this project, and the rest of the PLATFORM members, that has brought valuable feedback through the seminars and meetings.

I would also like to thank my fellow students of the MCT program, all of the professors and teachers, and all the questions that has been asked during the Music, Communication and Technology master.

[1] https://www.hf.uio.no/imv/english/research/projects/platform/index.html (accessed April 23th 2023) The PLATFORM project seeks to understand how tools for creating or producing music develops in the digital, online based environment.

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Chapter 1

Introduction

1.1 Purpose and Goal

The purpose of this master's thesis is to investigate the impact of approaches towards telematic communication and remote collaboration in the music and audio production industry. More specific, the study investigates the opportunities and constraints of three distinct collaboration approaches for users in collective songwriting and mixing productions, contextualized by affordance in existing Digital Audio Workstations (DAWs). The affordance is categorized based on DAWs features and functionality into Amateur, Mix-Centric, and Artist-Centric categories. The research aims to shed light on the future of music and audio production, particularly in remote production over the open internet. This research aims to describe and test principles of online distance music and audio collaboration that can apply to other linear and non-linear ways of collaborating. The findings of this research will provide insights into the opportunities and challenges of telematic communication and collaboration and its potential impact on the music and audio production industry. The present chapter presents the background of the chosen topics before presenting the research questions and the outline of the thesis. Their respective chapters will present the thesis' theoretical framework and results.

1.2 Motivation

Initially, my understanding of remote music collaboration was rooted in the idea of telematic performance and the linear nature of audio. My background as an audio engineer has fueled my fascination with the high-fidelity transfer of audio between remote locations and the technology that enables it. As a broadcast audio engineer, I have seen firsthand how remote processing and computing can effectively create a networked operation between multiple locations. This experience sparked my interest in exploring cloud-based solutions for producing linear and non-linear audio and video content.

Looking ahead, I anticipate that remote processing and computing will become an even more integral part of daily life for people across industries.

As climate change becomes an increasingly urgent issue, I believe that remote communication and collaboration tools will become essential for reducing carbon footprints and promoting sustainable practices. Thanks to advancements in technology, what were once abstract concepts are now accessible to professionals and amateurs alike. I am excited to delve deeper into the possibilities of remote collaboration and help pave the way for a more interconnected and sustainable future.

1.3 Background

Telematic communication and collaboration have experienced a drastic increase in the last ten years have been further accelerated by the Covid-19 pandemic (Vitagliano, 2021). Broader high-speed internet coverage enables professional broadcasters and consumers to use the same infrastructure and tools for distance production and collaboration. Before wide spread internet coverage, the transfer of audio and video for broadcasters has relied on expensive solutions such as satellites or telephone lines, sacrificing latency when using satellites, and quality when using telephone infrastructure. A popular term used in the broadcasting and film industry is *green production*, a practice aiming to reduce the production's environmental impact. In practice, implying less movement of people or goods to a location either to send it back to a centralized location, or part of the production solved in a more environment-friendly way[1]. Transfer of audio and video leads to new obstacles in terms of what's the most efficient way of solving latency, data transfer, and storage. In an organized environment such as broadcast, there is little room for creative collaboration, as most actions are planned and executed. Broadcast operations contrasts how Remote Music Collaboration Software (RMCS) operates, which relies on feedback from other collaborators, often in a unorganized environment. Still, RMCSs provide a valuable testing ground to understanding remote production principles, as they exhibit the same issues with latency and data volume as professional broadcasting solutions.

WEB 2.0[2] has made it possible to move software previously only available on the computer to the browser. An example is how text documents have moved into an online format with support for collaboration between users in a relatively synchronous environment. In music and audio, Bandlab[3] utilizes the same principles as online collaborative text documents; a collaborative environment in the browser where all participants have equal control over the project, defined in this study as a *Controller-Controller* approach. Still, several features and functions can not be found in Bandlab that can found in standard desktop-based DAWs. The reliability of Band-

[1] https://tech.ebu.ch/groups/greenproduction (accessed February 13th 2023)

[2] the second stage of development of the internet, characterized especially by the change from static web pages to dynamic or user-generated content and the growth of social media (Oxford Languages).

[3] https://www.bandlab.com/ (accessed February 5th 2023)

lab is beyond the users' control, in contrast to professional DAWs such as Pro Tools[4], Logic Pro[5] and Ableton Live [6], where their users prioritize the stability of the software, ensuring that the program functions reliably and without errors are of importance. Bandlab is not only a DAW but a social network for music creation and sharing. A project can be started clean, and published on the user's own Bandlab site, inviting others collaborate on projects. This platformization of DAWs aligns with the shift in music and audio production that has undergone in the past few decades, with DAWs playing an increasingly important role in replacing recording and producing environments. Reuter (2022) defines DAW 2.0 by stating that it is more device agnostic, running on operating systems across devices. This idea aligns with Strachan (2017), who states that the growth of accessibility to personalized computer and music software has narrowed the gap between the professional and amateur in terms of equipment, knowledge, practice, and sound. An integrated computer environment with all tools available has re-conceptualized how music production should be conducted (Strachan, 2017, p. 6).

The availability of tools from anywhere has eliminated the need for producers or artists to be restricted to a physical studio to produce music, consequentially leading to new modalities of what it means to be creative. The line between desktop computer software and online tools is becoming less distinct, expanding creative possibilities. Real-time collaboration with other collaborators in this multi-modal space can reshape the creative mindset of producers and artists, opening up new avenues for innovation and expression.

The aim of this thesis will be investigated through the following research questions:

Research Question 1: What are the opportunities and constraints of three distinct collaboration approaches for users in a collective songwriting or mixing setting?

Research Question 2: What affordance are there in the most used Digital Audio Workstations, and how does this affect the facilitation of remote collaboration?

Hypothesis 1: Each approach can be used to facilitate remote collaboration in its way, but it depends on the situation, users, task, and product desired. More than one approach is required to fulfill a end-to-end production, and several approaches must be used to obtain a finalized product.

Hypothesis 2: Existing platforms are designed based on who uses the platform, and not all platforms are utilized the same way. Affordance in DAW

[4]https://www.avid.com/pro-tools (accessed March 10th 2023)
[5]https://www.apple.com/logic-pro/ (accessed March 10th 2023)
[6]https://www.ableton.com/en/live/ (accessed March 10th 2023)

design affects how remote collaboration can be facilitated, as producers, artists and technicians have different requirements for a platform.

The study proposes to identify approaches used in remote collaboration of music production and songwriting as follows:

Asynchronous Approach (AA): The process of transferring files asynchronously, with limited real-time communication.

Observer Controller Approach (AC): The process of one collaborator in control over the session while the other participant(s) observe and comment in real-time.

Controller-Controller Approach (CC) The process of participants having equal control over the session and communicating in real-time.

With RMCS playing an increased role in how music is created and collaborated, the DAW market offers many software alternatives, ranging from user-friendly to complex software with advanced capabilities. Some DAWs specialize in specific tasks, while others aim to provide as many features and functions as the user can imagine. Although most DAWs share the same basic layout and functionality, their tools, features, workflow, and GUI differ. According to Strachan, Cubase and Logic were initially MIDI sequencers that later added audio support in the 1990s. In contrast, Pro Tools started as a hard-drive recorder and did not implement MIDI until 1999. When Ableton and FL Studio were released in 2001, there was an expectation that a multi-functional DAW that was not reliant on hardware should include everything in the box (Strachan, p. 75-79, 2017). Pro Tools continues to follow a "retro-imitation" or "skeuomorphic" design philosophy based on analog hardware, given its historical foundation as a recorder (D'Errico, 2022). Pyramix[7], a DAW primarily used for recording and mixing in ultra-high sample rates, follows a similar process-oriented design philosophy that prioritizes functionality over aesthetics.

The popularity of different DAWs varies depending on the context of their use. For example, a chart of the most common DAWs used in the UK Top Thirty Tracks from January 18, 2015 (Strachan, 2017, p. 44), reveals that Pro Tools was the most popular DAW, followed by Logic Pro, Ableton Live, FL Studio, and Presonus Studio One. In contrast, a survey by macProVideo.com (Sethi (2015), table 3.1) from the same period indicates that Ableton was the most popular DAW among home-studio users, followed by Logic Pro and Pro Tools. This data suggests that professional producers and mixing engineers favor DAWs prevalent in recording studio environments, whereas home studio users prioritize ease of use and affordability.

[7]https://www.merging.com/products/pyramix (accessed March 10th 2023)

The diversity in design philosophy of DAWs leads to a proposed categorization of DAWs. They are differentiated on the basis of features, functions and layout, and how they market themselves toward their users.

Amateur-Centric workstations are designed for beginner or amateur musicians/producers with limited functionality. Although they allow basic recording, they lack the advanced tools required for professional work. For instance, Bandlab provides simple creative tools for songwriting, but the virtual instrument libraries and the number of tracks are limited.

Artist-Centric workstations emphasize the creativity of the artist. These workstations can enhance creativity by offering functionality, routing, or a novel design layout, allowing the artist or creator to approach problems differently.

Mix-Centric workstations typically lack any reasonable limitation on the number of tracks, buses, or plugins that the creator can apply. Often serving less virtual instruments, they are designed with more focus on producers and mixing engineers, serving as an endpoint in the creative process.

It is argued in this study that the extent to which digital audio workstations are utilized shapes their effectiveness in supporting remote collaboration. Amateur-Centric DAWs, with their relatively limited feature sets, are well-suited for online environments and can be integrated into a Controller-Controller approach with relative ease or vice versa. In contrast, the higher complexity and use of Mix-Centric workstations means we are unlikely to see them operating in strict synchronous environments, and their intended usage is better utilized in a Controller-Observer- or Asynchronous environment as there is not as large demand for equal participation from several collaborators.

1.4 Scope, Limitations, and Contribution

The scope of this study is to test the principles of remote collaboration applicable to both linear and non-linear modes of collaboration, with a baseline of affordances in current workstations. The study focuses on the identification of digital audio workstations based on their usage and how remote music collaboration systems facilitate collaboration rather than examining the principles of network music performances, which are more pertinent in a remote recording environment. Although RMCS and NMP share similarities in connecting creators, RMCS' is not as latency dependent, and there are several different approaches towards RMCS that can facilitate effective collaboration compared to the linear state of NMPs. The major limitation of this study is the need for more participants in the experiment. To conclude with a statistically quantifiable outcome, further participants would have been needed. A more extended period for test-

ing would also be beneficial, as more perspectives and problems would be highlighted.

1.5 Methods

The study was designed to investigate principles of remote collaboration in music production. A multi-pronged approach was used that combined various research methods, including personal experiences within the field, analysis of existing platforms and solutions, and experimentation with three proposed approaches on a pair of users. The theoretical framework of the study was informed by the works of several scholars, including Strachan, Koszolko, Théberge, Mills, Sawyer, and Martin et al. who have conducted research within the field of technology and music production, the potential of virtual studio environments, and the effects of group dynamics in virtual environments.

Based on the theoretical framework and contemporary solutions for RMCS, an experiment were conducted involving a pair of participants. The experiment aimed to test the effectiveness and outcomes of three approaches to remote collaboration identified in this study against each other in a controlled setting[8]. The participants were tasked with working collaboratively on a music production project using each of the three approaches. The experimentation was observed, and a group interview was conducted with the participants to gather their perspectives and experiences. The interview provided an opportunity for the participants to share their insights and provide feedback on the approaches they tested. Their feedback was analyzed and integrated into the study's findings.

1.6 Outline of Thesis

The study comprises seven chapters. Chapter 2 covers the thesis's theoretical framework, explaining the impact of virtual environments in remote collaboration with a view on group dynamics, roles, and collective creativity. The chapter covers broadcasting solutions and how they approach latency and data in linear workflows. The approaches to remote collaboration identified in this study are presented at the end of the chapter. Chapter 3 discusses affordances in existing DAWs and suggests a categorization of them. The chapter continues to cover contemporary RMCS solutions that lay the foundation for the approaches proposed in chapter 2. Chapter 4 presents the methods, experiment design, and questions for the group interview. Chapter 5 presents the results obtained from the experiment. Chapter 6 presents the thesis discussion, conclusion, and possible future research.

[8]Further explained in section 2.4

Chapter 2

Collaboration in a Remote Environment

This chapter presents an overview of the theoretical framework for the study, solutions used by broadcasters and remote productions, and outlines the approaches to remote collaboration identified in this study.

Remote Music Collaborating Systems (RMCS) can be categorized as either synchronous or asynchronous in the way they interact with collaborators. Synchronous systems rely on continuous data transfer or communication between the collaborators, vs. asynchronous systems that do not rely on real-time transfer of data or feedback. This divide can have implications for the communication and structure of a collaboration. RMCS systems are different from telematic music performance, even though some of the same tools are present when collaborating over the internet. Telematic performances require a consistent and low latency to be facilitated, contrasting RMCS, which *can* operate with higher latency thresholds and more inconsistent *jitter*[1]. This is due to the *partly synchronized*[2] file transfer approach most often seen in synchronous RMCS, rather than real-time audio streaming seen in NMPs, which can disturb the performance.

Platforms for remote collaboration of audio and video production have been limited to institutions such as schools or broadcasting corporations that can justify the necessary infrastructure and a uniform choice of platform such as Blackmagic's Davinci Resolve[3] or Adobes Premier Pro[4] used in video production. These platforms can be synchronized with a centralized server or database to utilize a location-agnostic approach for where a project can be opened on the editing computers, often relying on an organized database, project structure, or a planned flow of data.

Individual users or small-scale users have the freedom to select their platform according to their preferences since they usually do not require

[1] Slight deviation or displacement of a linear signal

[2] Perceived as synchronized, even though there is a slight delay of file transfer. Participants of a session perceive the changes post factum. Opposite of true synchronous where there is minimum delay present, i.e. real-time transfer of audio.

[3] https://www.blackmagicdesign.com/products/davinciresolve/collaboration

[4] https://helpx.adobe.com/no/premiere-pro/using/collaboration.html

sharing or collaborating with others, and cross-platform interaction is not a concern for them. Audio can also be sent and received in a standardized manner, with limited impact on the sample-rate and bit-rate of a file between projects. The adoption of collaborative platforms for music and audio is still in its preface, with limited initiative and development done by the most prominent developers of DAWs such as Ableton, Apple, or Avid. As the market leaders, they can initiate platforms compatible with the users' existing projects and workflows, but collaborative environments developed by them is only seen in *Avid's Cloud Collaboration*[5]. The neglected initiative by market leaders leads to questions of how remote collaboration should be facilitated and executed in existing platforms, which again depends on conforming with the design and workflow already established in the DAW. In purpose-built RMCS platforms, the workflow, features, and functions must conform with the intended usage. As identified further in this study, approaches to remote collaboration do not fit all stages of collaboration and do not conform with all systems or workflows utilized in production environments. This leads to the proposed identification of RMCS into the following three approaches: *Asynchronous-Collaboration*, *Controller-Observer* and *Controller-Controller*. Each of the tree approaches facilitate collaboration in their own way.

The next part of this chapter will cover the study's theoretical framework to discuss how virtual and non-space environments has affected remote music production. The chapter will continue to cover broadcasting solutions, and end the chapter with an in-depth presentation of approaches towards remote music production identified in this study.

2.1 Virtual and Non-Space Environments

Increased internet coverage at home, work, and in-between has given us new possibilities in how we perceive interaction, collaboration, and connectivity, creating a non-space (Théberge, 2004). Consequently, giving creators the ability to be both device- and location-agnostic in their work and services for collaborative work has followed. The Covid-19 lockdowns have further fueled the same environments. It's assumed that all modes of virtual connectivity have undergone a significant transformation after lockdowns in 2020 and 2021, resulting in both amateurs and home users, as well as professionals adopting online environments as workflows. Bandlab saw a 150% increase in their users from 2019 to 2020 (Vitagliano, 2021), indicating a more significant adoption of online RMCS in this period.

But its not equal for all users how confident they are in online environments. Younger generations that have grown up under online circumstances can be more agile in confronting virtual and non-space environments. Limited research has been done in this field since internet users have grown significantly in the last 20 years. However, studies have been conducted on the difference between "digital natives" and "digital immigrants", where those who have grown up using the internet can adapt

[5]https://www.avid.com/pro-tools/cloud-collaboration (accessed May 7th 2023)

better to digital environments compared to older generations that had to adapt their workflows to fit into a digital environment (Reisdorf et al., 2019, p. 82). In the context of technical skills using the internet, it's argued that they matter just as much today as they did in the early days of the internet (Hargittai & Micheli, 2019, p. 110). The internet users of the 2020s don't see the behind-the-scenes mechanism, and consequently do not understand how and why it works, making it harder for them to understand how utilize internet tools to it's full potential.

As observed by Mills (2019, p. 6) , an online environment can relieve boundaries between creators and connect them in ways not imagined before.

> "While network technology collapses distance in geographical space, teleimprovisation takes place without the acoustic and gestural referents of collocated performance scenarios. This liminal experience presents distinct challenges for performers, e.g. negotiating the unknown in first online encounters with diverse musical cultures, interacting via new musical languages, practices, technologies, and expectations." (Mills, 2019, p. 6)

What Mills discusses here is the benefits and limitations of telematic spaces. The same can be seen in collaborative online environments which while they can present new opportunities, there are still challenges to overcome when conducting remote work, which is not the same as conducting work in the same physical spaces. Mills states that even though telecommunication provides affordances to augment tele-collaboration, there is still a considerable distance to cover before we can gain a comprehensive understanding of the social, cultural, and phenomenological aspects of human-to-human tele-improvisatory practices related to "transmission" (2019, p. 123-125).

Olson and Olson (2000) identified four critical concepts essential for effective collaboration at a distance: Common ground, Coupling or Dependencies of group work, the Motivation of collaborators to collaborate, and the Readiness of collaboration technology. Even though collaborators may be initially motivated to collaborate remotely, it is not always necessary to opt for online collaboration when a physical meetup is feasible. In these circumstances, the transition to carry out remote work can affect the motivation of actually starting an online collaboration, as it can be viewed unnecessary. While the technological readiness of RMCS can only partially replace a traditional *recording* studio, mobile studios, such as a laptop, may rely less on hardware, which can be replaced or augmented by virtual instruments or effects. Thus, using a platform with fewer features that facilitates collaborative modes can be advantageous in certain settings. Olson and Olson states that even with the emergence of new tools and social practices, distance still plays a significant role in collaborative work.

Théberge (2004) study of the "Networked Studio" states that interconnecting musicians and music production over the internet can be considered a "non-space" and "non-place", where the relationship between

physical space and musical outcomes are weakened. Additionally, Théberge has raised concerns about the lack of social interaction in a networked non-place, which may limit the exchange of informal ideas.

Spilker argues that the Network Studio can function as a "predistribution network", not to replace traditional studio workflows, but rather as a space to test ideas, and practice before moving into the studio environment. The creative process can happen outside of the studio, in the artist or producers virtual space, abandoning traditional studio practices as a place for end-to-end production. It is the multitrack recording studio that is regarded as the most common place where music is recorded and produced (Théberge 2012). Since both Théberge and Spilker published their articles (2004, and 2012), the idea of studio as an endpoint for a creative process or the outcome, has been shifted. As noted by Hracs et al. (2016, p. 11-22), this shift in location-agnostic thought has not only made it more accessible but also more popular.

M. Koszolko (2017) argues that synchronous systems facilitate composition in a more interactive way than asynchronous systems that rely on delayed feedback and revisions. He also says that in asynchronous systems, participants respond to a larger set of musical parameters than in synchronous systems, which can influense the effectiveness of working this way. M. K. Koszolko (2022) also states that to facilitate effective communication in RMCS, the collaborators are heavily influenced by the tools they use, such as chat rooms and commenting on work in progress. He also states that the style and choice of platform is not the limiting factor for work to be conducted in a virtual environment, as it can be moved to a platform that facilitates a higher level of technical sophistication at a later stage of finalization. However, the platform of choice still influences how the composition is facilitated.

Findings from Martin and Büchert (2020) suggest that that to enable effective online collaboration, participants must not ignore or abandon the most common and typical aspects of collaboration, where informal interactions are just as crucial as in a physical environment. A potential solution to this is videoconferencing tools. M. Koszolko (2017) observed that video allows for more immediate feedback compared to text-based communication in synchronous tools, observing that it created stronger bonds with his user and is a useful team-build tool.

2.2 Roles and Collective Creativity in RMCS

2.2.1 Roles

In the context of songwriting and production, several persons can be involved in the process. An article from Music Business Worldwide (Ingham, 2019) highlighted that the 2018 top 25 rap-songs in the US averaged 9.1 songwriters. This market is, of course, highly profit driven compared to independent artists.

Martin and Büchert (2020, p. 170) observed how traditional role labels

such as "producer" or "songwriter" can be helpful in co-present sessions, but in an online environment, these roles can feel more rigid and restrictive. They argue that a more open, collaborative approach, where students view themselves as "collaborative musicians," can lead to more productive and fulfilling collaborations. A "songwriter" may feel hesitant to add certain sounds or effects to their demo if they perceive it as overstepping the boundaries of the "producer's" role. They also point out the challenges of navigating rights, ownership, and authorship in online collaborations, particularly when participants bring in their pre-existing work, creating a sense of ownership over the work that hinders the collaborative process. They suggest that a more open, collaborative approach to online music-making can lead to more positive outcomes and a greater sense of ownership and investment in the resulting work. As the participants of their study did not test interactive cloud-based DAWs (identified in this study as Controller-Controller environments), this could benefit the creative process, as the participants are starting from a more democratic environment with equal power, and common gound. Martin and Büchert (2020) states as following:

> "The rigidity of sharing recordings in an online environment compared to the ephemeral and transient property of an idea suggested in a co-present writing room has clear causal effects on the process of collaboration. Online collaboration necessarily challenges the stability of traditional roles through the triangulation of personnel, location and technology and requires its own configuration of process." (Martin & Büchert, 2020, p. 170)

Their study concluded by presenting some necessary prerequisites, expectations, and methods for effective collaboration. One key aspect is the adoption of a non-hierarchical approach, where all collaborators share collective responsibility for the outcome. However, it is essential to note that not all approaches to online collaboration allow a non-hierarchical structure, as asynchronous or observation-based collaboration tend to have different role divisions, often focusing on a centralized *controller*[6], typically the producer.

M. K. Koszolko (2022) argues that most roles in remote production are performed by one person, the producer. In his previous work, he observed that the primary users of RMCS were amateurs (M. Koszolko, 2017, p. 30). Bedroom producers do not necessarily mean amateurs, but they often work independently, isolated from their co-creators, making them an excellent example of those who take advantage of RMCS to solve collaboration from isolation or distant location.

[6]Defined in this study as the person in control using the Controller-Observer approach. Further explained in section 2.4.

2.2.2 Group Creativity

As discussed by Spilker (2012), networked operations in music production can serve as valuable 'pre-distribution networks' that occur before the project enters the production phase. In this context, the concept of *distributed creativity* becomes instrumental in distinguishing between mere collaboration and meaningful interaction. Even though collaboration and interaction are linked, they present separate structures of improvised behavior. In Spilkers' description of networked studios as pre-production environments, creativity becomes paramount, fostering on developing an environment where innovative ideas can flourish and contribute to the success of the project. This distinguishing between organized events such as a broadcast, or an unorganized and creative process, such as producing a song, leads to the term *collaborative emergence*, defined by Sawyer and DeZutter (2009) as the unorganized part of distributed creativity. Collaborative emergence happens in one or more of the following scenarios:

- The activity doesn't have a predetermined outcome and is unpredictable.
- The results are shaped by the actions of each person in the moment, with each action influencing the subsequent actions of others.
- The impact of any individual action can be altered by the actions of others.
- The activity involves equal participation from all participants and is a collaborative process.

Sawyer argues that the creativity of a group depends on whether it displays collaborative emergence or not. In the context of RMCS, planning can determine how well a project is executed. Consequently, the momentary and sequenced actions of a delayed interaction in a collaboration could then affect the presence of collective emergence. The prominence of collaborative emergence can also be determined by the structure of the collaboration. The Controller-Controller approach has more of a democratic environment compared to the Controller-Observer approach where roles has to be clearly defined to determine who possesses power of the project. This can affect the presence of collaborative emergence, as there are no equal powers, equal participation, or results shaped or affected by all participants in the moment.

2.3 Networked Music Performance- and Broadcasting Solutions

Rather than focusing solely on remote music collaboration systems, it is worth examining the broader context of remote production and

performances as an example of how audio- or control-data are currently practiced in other states of behaviour.

For instance, network music performances offer insight into how latency impacts collaboration in a reactive environment where collaborators rely on each other's actions. Similarly, exploring remote broadcasting solutions can be useful to understand how data and processing can be managed within a network, which in turn can inspire more effective designs for remote music collaboration system, and approaches used.

2.3.1 Networked Music Performance and Latency

In network music performance, inherent system- and propagation-delay, combined with jiiter are the factors that affect the quality of service the most. To play music in real-time, musicians have a delay threshold of 25ms before they go out of sync. The latency varies depending on equipment, time of day, and broadband coverage in the area of performance. Carôt and Werner (2009) have developed some strategies to cope with latency when playing music over the internet. The three relevant to this study are:

Realistic Interaction Approach (RIA) assumes a stable one-way latency of less than 25ms. No change in musical output.

Master Slave Approach (MSA) assumes a latency beyond 25ms one way. Stepping back from musical perfection, the master does not listen to the return of the slave, and the slave plays along with the track from the master. If audience is present, they should be placed at the slaves' side, since this is where the music is in time.

Latency Accepting Approach (LAA), acceptance of the latency beyond 25ms, and uses it as a musical expression. Suits non-rhythmical music.

These approaches to managing latency affect the type and genre of music that can be played. A Realistic Interaction Approach does not restrict the performers and the music as it assumes no latency over 25ms one-way, compared to a Master Slave Approach, where one musician has to accept, or ignore the return signal that's out of synchronization. The Latency Accepting Approach suits music that is not latency-dependant, typically non-rhythmical music. In RMCS, these approaches are most relevant in remote recording sessions, or in broadcasting applications where a time-sensitive operation is in progress. For example in a broadcasting application where backing-tracks to the musicians are transmitted from location A (where the mixer is located) to location B (where the musicians are located), the placement of a delay to compensate the propagation delay is of importance.

2.3.2 Off-site Broadcasting Production

Traditional linear audio and video production often requires the transportation of people and equipment to a specific location. However, with the in-

creasing internet coverage, more roles can be centralized, and individuals or equipment can be removed from the location. Large broadcasting corporations frequently use this approach to communicate between their regional or international production locations or OB (Outside Broadcast)[7] locations. *TV2 Norway*[8] is one corporation that split its production and infrastructure between two cities(Lawo, 2021). Personnel can be located in Bergen or Oslo but still work on the same production. However, bandwidth and latency limitations restrict the scenarios that can be centralized or divided. For example, as the number of microphones and cameras increases, higher bandwidths are required to keep buffer latency low. No minimum bandwidth is recommended[9], but as shown in LAWO's case study on DPG Media (Lawo, 2020) where processing is located in Vilvoorde, and operations is controlled in Antwerpen 40 kilometers apart, 200 Gbps is allocated for their linear operations. In TV2's case, 40 Gbps is allocated for their linear operations between Bergen and Oslo, which is 300 kilometers apart.

2.3.3 Control-data Approach

One potential solution to address both bandwidth and latency in a system, is to position real-time dependent equipment at the side of transmission, thereby eliminating the transfer of latency-dependant data back and fourth from a site. This approach relies on control-data to be transmitted instead of the latency-dependant signals, for remote control of the latency-dependant equipment or operation. However, it is essential to carefully balance the benefits of centralization against the potential limitations of available bandwidth and the latency introduced in the control-signal. In RMCS this approach has already been implemented in browser based DAWs, where media is buffered in the browser, and a centralized server handles the changes of the session. Stickland et al. (2019, 2018) have designed a framework to address these problems in DAWs, scalable to 30 participants over residential broadband connection. The media is buffered at each participants end, and only the control-data is sent to communicate changes. While this approach may only be suitable for some collaborative audio project as there is not always a need for synchronous collaboration, it offers a potential solution to the challenge of data transfer rates in large-scale collaborative projects, as no large files are needed to be synchronized in real-time between computers. Rather it is the control-data which communicate the changes in the session.

In broadcasting control-data approaches has already been implemented in remote productions, or in large scale broadcasting applications such as those mentioned in section 2.3.2. Latency-dependent operations are mitigated by placing the mixing-core at the site of transmission, allowing an off-site technician to remote-control the mixing console or processing

[7] A broadcast operation that is situated away from traditional studios or control rooms. Used in live broadcasts of events.

[8] https://www.tv2.no/ (accessed 10th of May 2023)

[9] A lower threshold is of course needed, but in the context of complex operations, the bandwidth is not quantifiable.

core, or in a centralized server-park with all of the other processing of the broadcast. This approach can be facilitated easily, as most equipment, and in particular audio mixing consoles already operates digitally, and therefore, easily adaptable to a remote-controlled environment. By doing so, the technician can adjust the mix and monitoring levels in real-time remotely, ensuring that the recording or broadcast is synchronized with no sacrifice in loss of audio transmission. This approach has already been successfully implemented in the broadcasting industry. For example, LAWO[10], a manufacturer of digital mixing consoles, has developed an IP infrastructure that allows mixing-cores to be situated remotely from the operating console [11]. This enables technicians to adjust the mix and monitor levels at a remote location in real-time, even when they are not physically located in the same room as where the processing is situated, proving to be a highly effective solution for linear operations as it reduces the impact of propagation delay occurring when transferring audio over a distance.

2.3.4 Disadvantages of Relying on Networked Solutions

As technology advances, we are generating and transmitting more data than ever. Online data storage is becoming increasingly popular for storing and accessing information. However, there are some disadvantages to consider before moving to an all-online environment. One major drawback is the reliance on internet access. While some applications operate in peer-to-peer (P2P) networks, some rely on centralized servers to store data. For example, *Bandlab*[12] and *Soundtrap*[13] only offer online versions of their software. Users cannot access their projects if the servers are offline or their internet access is restricted, which can be a significant barrier to productivity and creativity in situations where users depend on project access.

Furthermore, the size of the data being stored can also be a significant issue. Video or audio projects can easily be tens of gigabytes in size. A high bandwidth connection is vital to upload and download these files quickly, which may only be available to some at some times. Moreover, as the project scales, the amount of data also follows, making the process harder if a plan or structure is not established.

The use of internet-based broadcasting solutions has become increasingly common, but recent events have highlighted some of the potential challenges associated with relying on the internet for this purpose. For example, the introduction of *Video Assistant Referee* (VAR)[14] in the top Norwegian football league, Eliteserien, demonstrated that even a stable and proprietary network connection provided by an internet provider can en-

[10]https://lawo.com/ (accessed May 9th 2023)

[11]https://lawo.com/remi-remote-at-home-production/ (accessed May 9th 2023) REMI/Remote/At-Home Production. Projects and Case Studies.

[12]https://www.bandlab.com/ (accessed April 10th 2023)

[13]https://www.soundtrap.com/ (accessed April 10th 2023)

[14]A referee that assists the main referee by reviewing footage from cameras on pitch.

counter problems[15]. In other words, VAR technology relies on a stable and high-speed internet connection to communicate with their centralized operations in Oslo. However, despite having a dedicated network connection, there were still issues with the reliability of the internet service during three matches at the same time. Theese events highlight that even when infrastructure is in place to support internet-based broadcasting solutions, there may still be inherent technical difficulties that can impact the user experience. It is also worth mentioning that this was the first official usage of VAR.

2.4 Approaches Outlined

Based on the solutions employed in broadcasting solutions and RMCS, three distinct approaches have been identified and proposed to classify methods of enabling remote collaboration in mix- and songwriting-contexts. These approaches were outlined based on how collaborative systems function, covered in chapter 3.

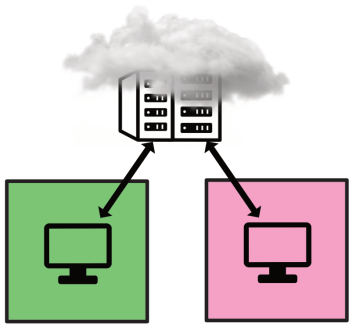

Figure 2.1: Asynchronous Collaboration

2.4.1 Asynchronous Collaboration

The first approach identified is Asynchronous Collaboration. It involves sharing files across different platforms without the need for real-time interaction. This approach is more suited for non-linear productions, where revisions can be sent back and forth between collaborators, and there is no need for reactive and immediate communication. There are different ways to achieve asynchronous collaboration, including sharing files over the internet or using plugins to share audio or MIDI across different DAWs.

[15]Documented by Norwegian Football Federation (NFF) https://twitter.com/nff_info/status/1645458030622801920 (accessed April 18th 2023) Introduction of Video Assisted Referee has been controversial, with both the public and the team management: https://www.vg.no/sport/fotball/i/P4EOv0/var-troebbel-i-eliteserie-starten (accessed May 4th 2023)

Asynchronous Collaboration is probably the most used approach, since there are very few dependencies in its manner of collaboration. Stems and audio files can be transferred between different platforms with relative ease. However, cross-platform compatibility when sharing anything other than stems, or sharing projects between different workstations can pose some problems, such as mismatched plugin-libraries or software versions. When transferring stems, signal-chains are often bounced together with the audio making revisions harder. The other main challenge with Asynchronous Collaboration is the bandwidth required to download and upload large projects, which can sacrifice efficiency, especially in projects dependent on many revisions between the collaborators.

Asynchronous collaboration is useful for non-linear productions where revisions can be sent back and forth between collaborators. While there are challenges with bandwidth and compatibility issues, specialized collaboration tools and features such as AVID's Cloud Collaboration can help make the process smoother and more efficient.

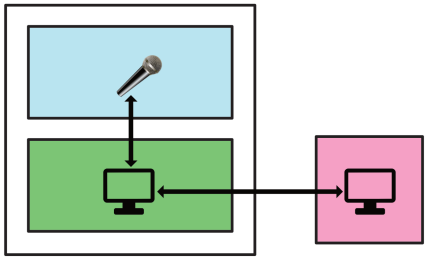

Figure 2.2: Controller-Observer

2.4.2 Controller-Observer

The second approach identified is the Controller-Observer approach. It differs from Asynchronous Collaboration by interacting in real-time between collaborators. Controller-Observer assumes a role division where one participant (the *Controller*) is in control over the platform, and the other participant (the *Observer*) watches and listen to the session in real-time, providing instant feedback and input. The Observer does not have any control over the actions of the Controller, thereby only possessing observational power. It is most valuable in a "producer-talent" situation where only one collaborator needs to be in control over the session.

The approach is versatile, as it can function with any platform and computer that can transmit audio and screen-sharing on the internet. The approach can also be used in educational or entertaining manners such as live-streams. The limiting factor of a Controller-Observer environment is the absence of equal power in the session.

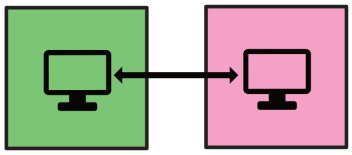

Figure 2.3: Controller-Controller

2.4.3 Controller-Controller

The third approach identified is the Controller-Controller approach. It can be explained as synchronous real-time platforms, where multiple participants share equal control over the session simultaneously. There are few music production platforms that operate by this principle, but the two most known platforms are browser-based Bandlab and Soundtrap. Other platforms that utilize this approach are synchronous word-processing documents. The approach eliminates the need to send files back and forth or wait for someone else to finish their work before making changes, as the environment is dynamic. All participants can see and hear the changes made by others in real-time, which can lead to a more fluid and efficient collaboration process.

Participants can communicate with each other in real-time through a chat function or videoconferencing, which can help to facilitate discussion and decision-making during the collaboration process, compared to the more sequenced Asynchronous- or absence of equal participation in the Controller-Observer approach. Controller-Controller environments are designed to allow multiple participants equal control over the session to facilitate more efficient collaboration between participants.

2.5 Summary

This chapter has presented an overview of the theoretical framework for the study and the proposed approaches identified to be used in remote music collaboration. The chapter has also discussed and presented the approaches used in broadcasting solutions and how they share problems similar to RMCS. The contemporary state of remote collaboration approaches will be further discussed in the next chapter, contextualized with affordance in DAW design.

Chapter 3

The Intersection of DAWs and Remote Collaboration Solutions

This chapter proposes a categorization of DAWs to address RQ2, understanding the affordances of existing workstations in relation to contemporary solutions for RMCS. Section 2.4 outlines three proposed approaches to RMCS, which is informed by this chapter. The chapter analyzes various DAWs to differentiate and identify distinct groups based on their unique combinations of features, functions, and workflow, which are categorized as *Amateur-*, *Artist-*, and *Mix-Centric*. The argument is that, most workstations share the same basic functions, but their layout and features determine their specific application or workflow. Therefore, it is important to present their affordances in this context. This work builds on previous unpublished research where workstations were categorized by their features and functions (Høydal, 2022).

The chapter will first talk about the background of DAWs, how they have become the way they are, and what we know about the usage of each platform. Then, the proposed categorization of workstations is presented, continued by a presentation and discussion of the workstations. The last part of the chapter will discuss first- and third-party applications that can be used to conduct remote collaboration in music production.

3.1 Platform Design and Use

In the late 80s, recorded audio became available in digital non-linear formats[1], and the traditional view of a two-axis software editor (y: tracks, x: timeline) emerged. The basic GUI of DAWs has remained relatively similar since the early 2000s, and most other DAWs model their design by the XY principle. In this study, a DAW is referred to as a software program either with or without hardware acceleration, using the XY principle. DAWs can

[1]Storage medium such as hard drives and solid state memory.

also be referred to standalone hardware which can also edit audio, or audio programming tools. This clarification is important, as audio workstations such as *Bespoke Synth*[2] or *MAX*[3] can resemble or emulate the principles stated in this chapter. A DAW is referred to the traditional workstations used by professionals and amateurs, such as Bandlab[4], Pro Tools[5] , Logic Pro[6] , and Ableton[7].

The basic function of a DAW is audio editing, recording, and mixing. However, they are different in terms of functionality and workflow. Ableton Live and Logic Pro are more focused towards creativity and songwriting. Others are focused towards technical abilities, and performance such as Pro Tools and Pyramix[8]. For example, Pyramix by Merging Technologies and Ableton Live can both do the same basic functions as recording and editing of audio. However, their tools and technical specifications are very different. They are designed to meet technical demands such as ultra high sample rate recording in Pyramix, or the horizontal live environment of Ableton. These affordances in their workflow and technical abilities define what environment they can be used in, even though both platforms are categorized as digital audio workstations.

Table 3.1: Ranking of the most popular DAWs from macProVideo.com (Sethi, 2015).

Ranking	Percentage %	DAW
1	23,14 %	Ableton Live
2	16,95 %	Logic Pro
3	15,13 %	Pro Tools
4	13,63 %	FL Studio
5	9,03 %	Cubase
6	3,80 %	Studio One
7	3,46 %	Reason
8	2,49 %	Garageband
9	1,99 %	Sonar
11	0,92 %	Digital Performer
12	0,77 %	Bitwig Studio
13	8,70 %	Other

There is no clear data on how many users each platform has. An article from SoundsWow (Donovan, 2022) claims that 20% of all producers use Logic Pro. That number only represents the number of producers and not the total number of users. As mentioned in the introduction of the study, an overview of the UK top 30 tracks in January 2015 shows that Pro Tools were the most used platform, followed by Logic Pro and Ableton (Strachan,

[2]https://www.bespokesynth.com/(accessed April 26th 2023)
[3]https://cycling74.com/products/max (accessed April 26th 2023)
[4]https://www.bandlab.com/ (accessed February 5th 2023)
[5]https://www.avid.com/pro-tools (accessed March 10th 2023)
[6]https://www.apple.com/logic-pro/ (accessed March 10th 2023)
[7]https://www.ableton.com/en/live/ (accessed March 10th 2023)
[8]https://www.merging.com/products/pyramix (accessed March 10th 2023)

2017, p. 44), contrasting the survey from macProVideo.com at the same time period, revealing that Ableton, Logic and Pro Tools were the most popular, shown in table 3.1 (Sethi, 2015). The survey from macProVideo is based on their readers, compared to UK Top 30, which the production originates from professional environments. This difference in numbers and data shows that usage depends on situation and task, and not all workstations are suitable for all situations. Théberge claims in his study of US and Canadian music studios that almost all of them had one sort of Pro Tools compatibility (Théberge, 2012, p. 85), leading to it being considered the industry standard. Strachan (2017, p. 50) states that the availability of personal computers, and the relative ease of obtaining software, affects the modes of collaboration within the economy of music production. Focus is drawn away from the recording studios, and into the personal computers of the creators.

3.1.1 Affordance Categorized

The following categories have been identified and are proposed to be used as a guide to explain affordance in DAWs: Amateur-Centric, Artist-Centric, and Mix-Centric. These categories are not rigid, as a DAW can fall into more than one category but they can serve as a guide to understand how workstations are designed.

Amateur Centric workstations are categorized as workstations with limited functionality, focused on the beginner/amateur musician or producer. They can do basic recording, editing, and producing but cannot expand into the higher level complexity needed for professional work, limiting the toolset available. For example, Bandlab offers simple creative tools for songwriting but limits the virtual instrument libraries and the number of tracks available. While these DAWs may have a different functionality than professional workstations, they can still be effective tools for those who are just starting out and learning the basics of music production. They can help beginners develop their skills and gain confidence before moving on to more complex and advanced software.

Artist Centric workstations are based on the creativity of the artist or producer. They often disregard the recording and mixing part of a project, and favours the production or performance process. For example, FL Studio's sample-based workflow is centered around the sampler and sequencer, allowing for easy creation of loops and patterns. The interface is designed to be visually appealing and intuitive for creative experimentation, with a focus on step-sequencing and automation. However, FL Studio has limited recording capabilities compared to other DAWs and may not be the best choice for more traditional audio editing and mixing tasks.

Mix Centric workstations usually do not have any reasonable limitation in the number of tracks, busses, or plugins that the creator can apply and are generally designed to facilitate audio recording, editing, and mixing tasks,

with a focus on creating polished, professional-sounding mixes. Some examples of Mix-Centric DAWs are Pro Tools, Logic Pro, and Cubase[9]. Their primary function is to be an endpoint in the creative process - releasing recorded music or audio straight from the DAW to the desired platform or format. In general, Mix-Centric DAWs prioritize audio quality and editing/mixing capabilities over creative experimentation and linear workflows.

3.2 Overview of Digital Audio Workstations

This section provides an overview of DAWs, focusing on their technical capabilities. The aim is to demonstrate that each DAW possesses unique features and limitations that shape its usage. Based on initial sorting, Ableton and FL Studio are categorized as Artist-Centric, Pro Tools and Logic Pro as Mix-Centric, and Bandlab and Soundtrap as Amateur-Centric. The section also discusses Soundtrap and Bandlab in a collaboration setting.

3.2.1 FL Studio and Ableton

FL Studio and Ableton have been selected as an example of Mix-Centric workstations. They market themselves towards creators, with extensive support for virtual instruments.

FL Studio has gained popularity among DJ producers and electronic dance music (EDM) artists since its initial release in 2000. While it was originally developed as a drum machine, it has since evolved into a full-fledged DAW with an object-oriented layout that presents all features and functions most of the time. However, this design is the opposite of simplistic, with a number of buttons and windows greeting the user upon opening the DAW. The layout of FL Studio is centered around three main windows: *Playlist* (also known as Arrangement), *Pianoroll* (a MIDI editor), and *Channel Rack* (the drum machine for each clip in the Playlist/Arrangement). These three windows offer multiple arrangement views at the same time, making FL Studio very versatile with multiple ways of performing one function.

FL Studio offers 125 recordable and mixable tracks, and its top-tier version comes preinstalled with a large library of effects. The DAW can record multiple tracks at the same time, but recording is not its primary functionality. FL Studio offers two recording options, *Edison* and *Playlist Record*: Edison functions as a plugin, which works as a sampler and stores the track as a clip. Playlist Recording records straight onto the track(s). While playlist recording works like other DAWs, FL Studio asks the user to give a new name for each recording, which is not standard in other DAWs. When it comes to editing, FL Studio is primarily built for editing samples and MIDI. It offers the same basic editing functionality as other DAWs, including fades, automation, and splicing. However, audio

[9]https://www.steinberg.net/cubase/ (accessed May 7th 2023)

editing happens in Edison, which is a destructive editor. This means that any choices made for a recording or clip will be permanent, making it unsuitable for multi-clip editing. Sequencing, on the other hand, is what FL Studio is built for. Each sample/clip can be edited on its own, and inserted into the playlist as a new sample.

FL Studio markets itself as an extension of what you can do with a DJ kit, rather than a fully-fledged DAW. Its marketing is heavily influenced by popular EDM and hip-hop artists. FL Studio offers lifetime updates and *"endless creativity"*[10], which is its main selling point. They also claim they are the *"fastest way from your brain to your speakers"*[11].

Ableton has a simplified, clean aesthetic, process-oriented design with two main views: *Session* and *Arrangement*. Session is meant for live-use and displays tracks vertically with *Clip*[12] spots that can be used in different *Scenes*[13]. Arrangement displays tracks and audio in a timeline for editing using the standard XY-layout. Plugins and effects are separated in their own window at the bottom and are meant to be used on a clip-level, meaning they are inserted on a clip, rather than a track in Session view. *Standard* and *Suite* versions of Ableton have unlimited audio and MIDI tracks, scenes, send and return tracks, and can utilize all input and output channels of the interface. The *Lite* and *Intro* versions limit the number of features available. Ableton has an extensive MIDI-plugin library for all of its tiers, but it grows in size with the tiers.

Ableton presents the creators with endless opportunities to structure their projects, oriented towards a combination of studio-work and live-work, closing the gap between produced material and performances on stage. Ableton focuses on virtual instruments and MIDI capabilities, with support for extensive routing of audio and MIDI in and out of the DAW. Ableton also has integrated *Max for Live*[14] into their Standard and Suite tiers. The DAW is not mainly designed for multitrack recording and mixing but to bring a mix out of a studio environment to a stage, enlightening creativity by not limiting the user. Therefore, it is more of an Artist-Centric workstation than a Mix-Centric workstation.

3.2.2 Pro Tools and Logic Pro

For Mix-Centric workstations, Pro Tools and Logic Pro have been selected. Logic Pro supports extensive support for virtual instruments and songwriting tools, and therefore to a greater extent, an Artist-Centric workstation compared to Pro Tools. This shows that affordances in the design do not cater to one specific categorization proposed in this chapter.

[10]https://www.image-line.com/ (accessed October 29th , 2022)

[11]https://www.image-line.com/ (accessed April 27th, 2023)

[12]Scenes on a specific track in Ableton Session View. Can be triggered individually, or collectively by a Scene.

[13]A collection of Clips in Abletons Session View.

[14]Integration with Max MSP, a visual audio programming language https://www.ableton.com/en/live/max-for-live/ (accessed May 7th 2023)

Pro Tools, is considered to be the industry standard for post production and mixing, making it the go-to choice for professional audio editors and mixing engineers situated in studios. AVID has been offering Pro Tools in various versions for years, starting with a free *Intro* version, then standard *Pro Tools* and *Pro Tools HDX*. In recent years, they have switched to a subscription model, offering *Intro*, *Artist*, *Studio*, and *Ultimate* versions. The difference between Pro Tools tiers is the total number of mixable MIDI and audio tracks, simultaneous recordable tracks, busses, and sums. Avid has a program for universities, colleges, or private institutions where their students can become certified users. The layout of Pro Tools has remained relatively consistent since its introduction. Users have two main views, *Mix* and *Edit*, with transport and editing controls at the top. The design of Pro Tools uses retro imitation to simulate physical knobs and buttons, which gives it a classic look. In terms of functionality, Pro Tools offers 64 simultaneous record inputs, 512 audio tracks, 1024 MIDI tracks, and multichannel mixing in surround with Dolby Atmos and Ambisonics. The Studio version can only support up to 64 tracks, while the Ultimate version can support up to 384 tracks via Core Audio or ASIO drivers in OSX and Windows. Additionally, Avid sells hardware that can enhance the mixing and recording experience, with both extensions of recording capabilities and acceleration of virtual software instances, increasing recording capabilities up to 2048 tracks [15].

Pro Tools is widely recognized as the industry standard for audio editing and mixing, with support for extensive audio editing and recording capabilities. One of its main selling points is its reputation for stability and familiarity. With the new lineup of versions, AVID is trying to expand the market to include amateurs and semi-professional users as well.

Logic Pro is one of the most used DAWs, alongside Ableton and Pro Tools. It has received free updates since 2013, making it an affordable option for those looking for a reliable DAW in an OSX environment. Logic Pro continues a similar layout to *GarageBand*[16], as well as being able to open GarageBand projects and Logic projects as old as Logic 5, maiking Logic Pro the natural transition DAW from GarageBand. The difference between them is more features, a Mixer-view, and a more extensive plugin-library. Logic Pro also has a vertical layout called *Live Loops* and *Step Sequencer* which makes it similar in layout and functionality to Session in Ableton and Channel Rack in FL Studio. Logic Pro comes with many pre-installed pluings and features, including Dolby Atmos, support for up to 1000 stereo tracks, up to 1000 MIDI tracks, and 13,000+ Apple Loops. Logic Pro provides standard editing tools, and native support for time-flex, pitch correction, and comprehensive automation support. Apple markets Logic Pro as "ridiculously powerful and seriously creative"[17], claiming to cover most needs in a workstation. It is designed to "just work" as any other Apple product. The

[15]https://www.avid.com/resource-center/exploring-increased-voices-tracks-and-io-in-pro-tools-2021-6 (accessed May 6th 2023)

[16]https://www.apple.com/mac/garageband/ (accessed April 15th 2023)

[17]https://www.apple.com/logic-pro/ (accessed April 26th 2023)

layout imitates what's seen in Garageband, making the transition over to Logic Pro easy for those familiar with the pre-installed software on every Mac. Logic Pro is a reliable and versatile DAW that has become a go-to choice for many music producers and audio engineers. They also have an educational program that focuses on educational institutions, but it is not as comprehensive as AVID's educational program.

As a go-to workstation for many users, Logic Pro tries to catch them all with tools for music production, creation and recording. As Apple states, it's a "powerful software" that can do some of it all. This makes Logic Pro harder to categorize than Pro Tools Mix-Centric orientation, since Avid heavily focuses on the professional market with educational programs, and hardware-acceleration. I would argue that Logic Pro is a Mix-Centric workstation with a nuance of Artist-Centric, as it tries to imitate workflows seen in Ableton and FL Studio.

3.2.3 Bandlab and Soundtrap

In this section, Bandlab and Soundtrap is presented. They are in this chapter categorized as Amateur-Centric and Synchronous Collaborative Platforms [18]. Both platforms lay the foundation for this thesis definition of Controller-Controller environments as stated in section 2.4. Bandlab and Soundtrap differ from standard desktop-based DAWs by not offering any hosting of plugins or instruments and that they can be accessed anywhere with internet access. It does not matter what system the user uses, as only a compatible browser is needed. There are also legacy DAWs, such as *OHM Studios*[19] that could run as a desktop program. But this section covers Soundtrap and Bandlab in the context of Amateur-Centric workstations in Controller-Controller environments based their limiting functions and tool-sets, and their extensive collaboration functionality.

Bandlab is a browser-based music creation and social networking platform that allows musicians to create, collaborate, and share their music online. It was launched in 2016 by Bandlab Technologies. Bandlab also functions as a social media that enables users to create a profile and connect with other musicians through its online community. Users can create and join groups, participate in forums and discussions, and share their music with others. The layout is similar to desktop-based platforms, following a XY-layout and a process-oriented design with transport functions, metronome, and volume control at the top and tracks below. The maximum number of plugins is 8, and the maximum number of tracks is 16. Projects are limited to a length of 15 minutes. Bandlab offers 313 virtual instruments but no *VST*[20] or plugin-hosting support. Recording functionality is limited to one track at a time, and editing is basic with functions like fades, cuts,

[18] Platform for synchronous collaboration between users. Covered further in section 2.4.

[19] https://www.ohmforce.com/ (accessed May 6th 2023)

[20] Virtual Studio Technology, a protocol used to integrate plugins or virtual instruments across DAWs.

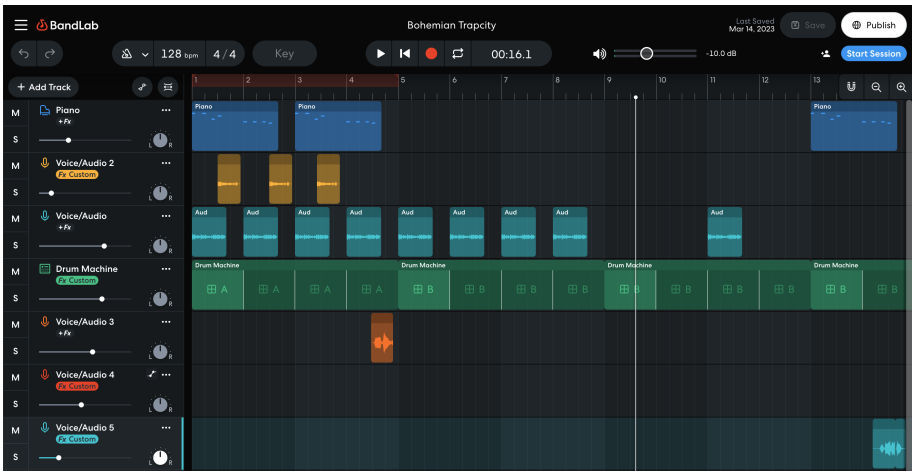

Figure 3.1: Bandlab Interface

automation, flex functionality, and MIDI quantization. Users can collaborate on music projects in real-time, regardless of their location, and share their work with others on the platform's website. Bandlab also includes features for live-streaming out of the DAW, where users can broadcast their music production to their followers on Twitch or YouTube with contests and challenges to encourage creativity and collaboration with their followers. Its main selling point is Bandlab's collaborative and social interactive features, as its design is limited compared to other full-fledged DAWs. The platform is compatible across multiple devices and platforms, with support for most modern browsers on desktop, iOS and Android.

Soundtrap is a browser-based DAW that allows musicians, podcasters,

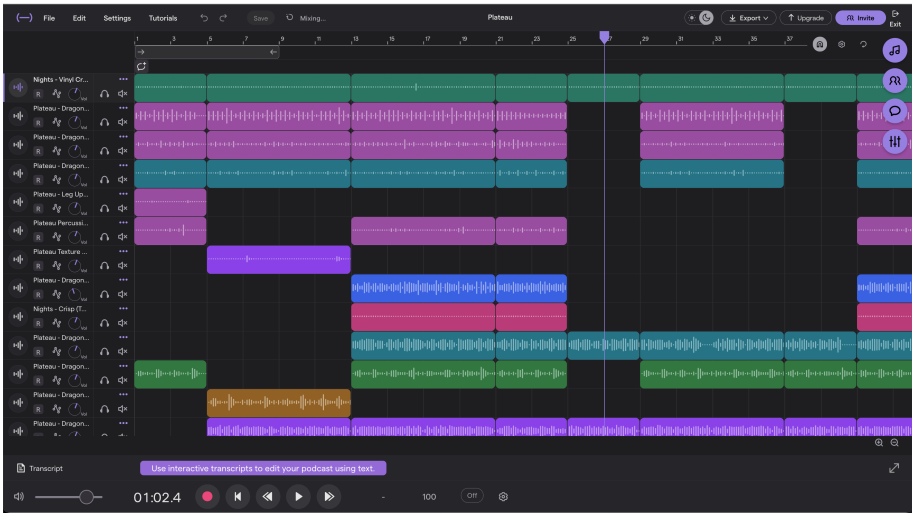

Figure 3.2: Soundtrap Interface

[20]Figure 3.1 image source: https://www.bandlab.com/studio/ Screenshot (accessed April 14th 2023)

and other creators to record, edit, and mix music and audio online. It was launched in 2013 by a Swedish company of the same name and was later acquired by Spotify in 2017. They market themselves towards educational purposes and amateurs, designed to be an easy-to-use and collaborative platform for music and audio production. Unlike Bandlab, it does not have a social network of user-generated content. However, it allows users to work on projects in real-time with other collaborators, regardless of their location and provides a basic but functional DAW. The layout is simple and process-oriented, with transport functionality at the bottom and controls for recording, volume, automation, solo and mute on each track. There are no limitations on project length, tracks, or the number of recordable tracks, working until the computer or browser can't handle the session anymore. The *Free* version offers 4920 loops, 440 instruments and a library of sounds. The *Complete* version offers 22480 loops, 940 instruments and sounds, and transcription of speech-to-text for podcasts. Soundtrap markets itself as an educational platform for schools and has simplified music production by including automated chord suggestions, audio quantization, and audio-to-MIDI conversion, making it easy to create music without requiring a deep understanding of music theory or production techniques. Soundtrap also provides a podcasting studio that allows users to video chat while recording a podcast. The studio stores the recording of remote participants in the cloud, separate from the audio transmitted over the internet in real-time to the other participant in the podcast. The platform also offers direct publishing of podcasts to Spotify, keeping the entire process within their ecosystem. The platform is compatible across multiple devices and platforms, with support for most modern desktop browsers, iOS and Android.

As an honorable mention, **Ohm Studio** was a DAW developed by Ohm Force. The project is not in development anymore, but it has been documented in research on collaborative DAWs previously (M. Koszolko, 2017). Claimed by themselves as the first desktop-based collaborative DAW [21]. The key difference between OHM Studio and its present online successors is its ability to host third-party plugins and act more as a traditional desktop DAW. Ohm Studio uploaded everything to the collaborating space immediately, in the same way as Bandlab and Soundtrap functions.

Bandlab and Soundtrap both aim towards educational and accessible markets. It is clear that both platforms share similarities in their design, but Bandlab has a limiting design by not including all features to the user. This contrasts how Soundtrap does not limit the number of tracks, and length of projects. The design may be of intent to Bandlab, since they focus on the social aspect of their platform. Thereby creating a uniform set of tools for creators to use, and to collectively create and react upon.

[20]Figure 3.2 image source: https://www.soundtrap.com/studio/ Screenshot (accessed April 14th 2023)

[21]https://www.ohmforce.com/technology (accessed May 6th 2023)

3.3 RMCS Inside and Outside the DAW

This section presents tools that facilitate collaboration, which can be integrated within the digital audio workstation or offered as a third-party plugin or service. The first part presents cloud synchronizing software that integrates to DAWs, followed by collaborative online platforms specialized to communicate feedback outside of a DAW effectively. The last section covers solutions for real-time transfer of audio over the Internet.

3.3.1 Cloud Integration in DAWs

The platforms covered here are *partly synchronized software*, meaning the collaborators can choose what parts of a session they want to share. The collaborators can *push and pull* [22] files, choosing what they want to have in their local session and what they want to share with the collaborators. The benefit of this workflow is that a collaborator can work on a section without interfering with the other collaborators' work. It is similar to the Controller-Controller environments seen in Bandlab and Soundtrap, but the collaborators work in their own spaces and not in a completely democratic environment.

Avid Cloud Collaboration (ACC)[23] is a feature within Avid's Pro Tools that allows multiple users to work on the same project partly synchronized. It was introduced in Pro Tools 12 and is designed to improve the workflow of collaborate remotely. With ACC, users can share audio files, session data, and project settings in the cloud, and collaborate on projects. This allows multiple users to work on different aspects of a project simultaneously, such as recording, editing, mixing, and mastering, without interfering with each other's work. ACC also includes version control, which allows users to keep track of changes and revisions in a project, as well as chat and commenting tools, which allow users to communicate and provide feedback within the Pro Tools session. Tracks can be *frozen*[24] to allow for compatibility with signal chains or plugins that may only be available for one participant. This also reduces the need for multiple uploads and downloads within a project.

Satellite Studios[25] plugin-bundle by Mixed In Key is a collaboration tool that allows for seamless sharing of audio and MIDI files between any DAW. By functioning as a plugin, Satellite Sessions ensures collaborators can work on the same project while adhering to the same key and tempo. This tool eliminates the need to learn a new collaborative space or workflow as it functions with all DAWs. Satellite also eliminates bouncing, and transfer of audio outside of the DAW. The plugin-bundle consists of three parts:

[22] The action of uploading and downloading files from a repository.

[23] https://www.avid.com/pro-tools/cloud-collaboration (accessed May 7th 2023)

[24] Tracks are frozen or locked so other participants of the session cant edit them, and stops synchronization of those tracks.

[25] https://mixedinkey.com/satellite/(accessed March 10th 2022)

Satellite Session, *Satellite Audio*, and *Satellite MIDI*. Satellite Session acts as a portal for transferring and receiving files, while Satellite Audio and Satellite MIDI enable the sharing of audio and MIDI files. Collaborators can preview shared MIDI files before importing them into their DAW with an internal MIDI playback engine. The timeline and bars in the Satellite Session plugin correspond to that of the DAW, synchronizing workflow for all collaborators.

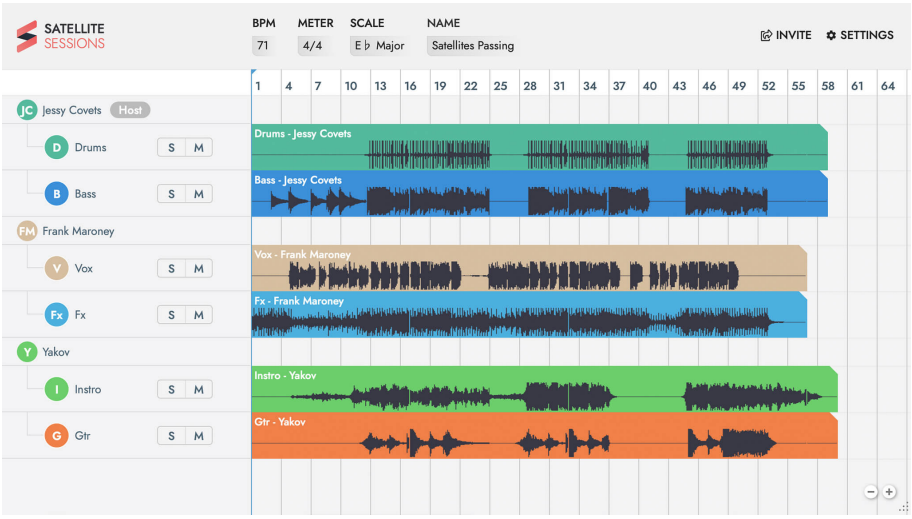

Figure 3.3: Satellite Plugin Interface

3.3.2 Collaborative Online Platforms

Compared to the partially synchronized platforms, there are the fully asynchronous platforms that offer specialized collaboration tools such as LANDR [26], Audome [27], Filepass [28] , and Mixup [29], which are designed to allow users to discuss and comment on audio files. Their main purpose is to limit the upload and download of raw audio files over filesharing platforms and to keep communications inside one contained space instead of over email or other text-based communication tools.

LANDR is a website that provides a communication platform for music creators. It offers AI mastering, a marketplace for creators, and a tool for collaborating remotely with other musicians. With LANDR's collaboration platform, users can share their projects with collaborators and receive time-stamped comments. The platform's collaborative tool lets users reply with audio or video messages, as well communicating via video chat that can

[25] Figure 3.3 image source: https://mixedinkey.com/satellite/ Download (accessed April 14th 2023)
[26] https://www.landr.com/ (accessed March 10th 2022)
[27] https://audome.com/ (accessed March 10th 2022)
[28] https://filepass.com (accessed March 10th 2022)
[29] https://mixup.audio/ (accessed March 10th 2022)

also stream high-fidelity audio.

Audome and Filepass are two commonly used platforms for providing feedback and collaborating on revisions in the music production industry. Although they do not offer as extensive a range of features as LANDR, their functionalities are more limited to the feedback and revision process. Both platforms provide the capability to restrict downloads of tracks, and manage roles and access for those with access to the files or links. Audome offers the added benefit of keeping track of revisions made to a song, thereby simplifying the naming and management of revisions for both clients and producers.

3.3.3 Real-Time Transfer of Audio

In this section, synchronous real-time transfer of audio is covered. Even though there are many different solutions for transfer of audio, two have been selected in this section. The first one is LISTENO[30], a platform that integrates as a plugin and offer user-friendly settings and sharing of audio. The other one is Jacktrip[31], a versatile software that can expand out of the DAW. Both solutions can be used for the same task, but they represent two different aspects of audio transfer over Internet.

LISTENTO by Audiomovers is a real-time audio streaming platform that allows users to broadcast high-quality audio from their DAW to listeners on a private network. What sets LISTENTO apart from other real-time audio transfer software is its integration as a plugin in the DAW, eliminating the need for internal routing software such as VB Cable [32] or Loopback [33]. This makes sharing audio with collaborators easy and hassle-free, without bouncing tracks or sending files via email, given that the collaboration happens synchronously. With support for up to 16 audio transmission channels, the collaborators can transfer audio for many different needs. Using a proprietary streaming protocol, LISTENTO offers low-latency, high-fidelity audio, enabling collaborators to listen to the project remotely on their own speakers or headphones. LISTENTO can also be listened to outside of a DAW, and can send the stream to a browser or mobile application, making it accessible and user-friendly.

Jacktrip is an open-source software application that enables high-quality, low-latency audio transmission over the Internet. It is designed to facilitate real-time musical collaboration, performance, and recording between musicians in different locations. One of the key features of Jacktrip is its ability to support multiple channels of audio, which allows for complex musical arrangements and ensembles. It also provides several configuration options, such as buffer sizes and sample rates, that can be optimized

[30]https://audiomovers.com/wp/listento/
[31]https://www.jacktrip.com/technology (accessed 6th of April 2023)
[32]https://vb-audio.com/Cable/ (accessed 6th of April 2023)
[33]https://rogueamoeba.com/loopback/ (accessed 6th of April 2023)

for specific network conditions and hardware setups. Jacktrip can also be configured in many different ways, allowing several participants to join a session or to transmit audio over a larger network.

Other alternatives for low latency streaming of audio is JamKazam[34], SoundJack[35], and LOLA[36], with the latter software supporting video streaming for network music performances.

The key difference between Jacktrip and LISTENTO is their integration and purpose. LISTENTO integrates as a plugin in the DAW, eliminating the need for internal routing software. It is mainly used for remote collaboration and broadcasting of audio in the music production and audio engineering industry. LISTENTO also offers convenient listening alternatives, such as streaming in a browser or mobile application. Jacktrip is designed for remote musical collaboration, while LISTENTO is designed for remote broadcasting and collaboration in music production and audio engineering. Essentially they serve the same function; low-latency, high-fidelity streaming of audio over the Internet.

Recording Remotely

Currently available platforms and software are not designed for remote recording sessions, where the talent is located separately from the producer. The fundamental problem in doing this is the propagation delay between sending a file from the producer, responding, and then recording it, as covered in sections 3.3.3 and 2.3.1. To record remotely, it is best facilitated in scenarios where each collaborator or musician records their section on their own, to be collected by a centralized producer, or to be added into a democratic space such as a Controller-Controller environment. In a distributed recording environments, there are no off-the-shelf option for delay compensation. In situations where only the recording engineer, or producer is located remotely, delay is not a problem as all signals travel the same distance, given that there are no audio that is transferred to the site of musicians, where the delay would have to be compensated.

[34]https://jamkazam.com/
[35]https://www.soundjack.eu/
[36]https://lola.conts.it/

3.4 Summary and Discussion

The present chapter presents an overview of the proposed categorization of affordances in the most popular DAWs on the market, together with new collaborative platforms that present an online, browser-based Controller-Controller environment. The chapter also presents an overview of contemporary solutions for production of audio in existing platforms, and how it is facilitated. The tools and platforms presented in the last part of this chapter can adapt to existing workflows and environments with ease, making them suitable for collaborators that want to take advantage of their existing workflows or platforms.

When categorizing affordance in the most popular DAWs, each workstation has its own unique qualities, making it challenging to categorize them strictly into one category. The proposed categorization of workstations is a generalization, with Bandlab and Soundtrap following Amateur-Centric design since it limits the capabilities in the software. FL Studio and Ableton offers more artistic freedom following an Artist-Centric design, and Pro Tools and Logic Pro are oriented towards a Mix-Centric design. As discussed, Logic Pro has a nuance of Artist-Centric in its workflows and features. The selected features in this chapter are an attempt to showcase the essence of each workstation, but there are still other features and functions not covered in this chapter, such as the extent of editing capabilities, pre-installed plugin design and amount, and integration to a larger ecosystem. The lack of data from the usage of platforms also constitutes to some problems as there is no answer to state what DAW is the industry standard in specific fields. As Théberge (2012, p. 85) noted, in 2012 almost all traditional recording studios had support for Pro Tools. Strachan (2017) suggests that there is no industry standard of workstations, as the UK top 30 tracks in 2015 lists 15 other tracks that is not produced within Pro Tools. This indicates that even though professional recording studios use Pro Tools, producers that are dependant on laptops with stand-alone software, may not take advantage of hardware acceleration or integration of hardware controllers within their DAW. This environment of location-agnostic workflow can also employ a platform-agnostic thought across producers, as there are no dependencies in the choice of platform for producers.

This device- and location-agnostic thought leads to how remote collaboration is facilitated today. The collaboration facilitating platforms presented in section 3.3 can be used with any pre-existing DAWs, except Avid's Cloud Collaboration which is proprietary to Pro Tools. The partly synchronize software of Satellite Studios and Avid Cloud Collaboration presents possibilities to collaborate in partly synchronized environments, without *committing*[37] to a whole session or bouncing stems to transfering them outside of the DAW. The collaborative approach and design is similar to Bandlab and Soundtrap, but the defining difference is that the user can select what data

[37] The action of transferring data to a database or client

they want to contribute, and receive, meaning that they are not fully democratic synchronous environments, but rather a partly synchronous environment. The approaches used here are a variant of a Controller-Controller environment, as it's expected using them that the collaborators have a real-time interaction. The collaborators still don't have full control over each others environments, as editing, mixing, and recording happen locally at each collaborator's DAW.

Platforms such as LANDR, Audome, and Filepass can facilitate asynchronous collaboration by offering a collaborative platform for effective communication and feedback between collaborators. They utilize both synchronous and asynchronous collaboration approaches to create a co-working space for creators and collaborators. Their approaches assumes a organisation in the production, and they do not offer creative input to the product.

Real-time transfer of audio can be done via software such as LISTENTO and Jacktrip. LISTENTO specializes in DAW transfer of audio, compared to Jacktrip that functions more as a standalone transfer software. They can be used in combination with videoconferencing tools to allow collaborators to listen to remote mixes on their own systems or computers.

In the next chapter, the study's methodology is presented together with the experiment premises. The experiment was designed to test the three approaches outlined in section 2.4 in a practical setting. The results from the experiment will be combined with the results form this chapter to answer the research questions.

Chapter 4

Methods

The study was designed to investigate principles of remote collaboration in music production. Previous studies on RMCS, literature about group dynamics, broadcasting solutions, digital communication, and collaboration has been used as a baseline for the discussion and conclusion. A multi-pronged approach combined various research methods, including personal experiences within the field, analysis of existing platforms and solutions, and an experiment to test the three approaches towards remote collaboration outlined in the thesis. The experiment was designed to identify constraints, opportunities, and the impact each of the three approaches has on a remote production environment. The study's outcome was to understand how approaches to RMCS can be used and how they are adapted to the workflows of producers, songwriters, and audio engineers.

The experiment involved two participants who tested the three approaches in a songwriting and mixing environment. Each participant contributed to the session with either a software-instrument or an acoustic instrument, and both participants collaborated on mixing the song. No constraints were set regarding the complexity of the material. The participants had backgrounds in music technology and were confident in telematic communication, having used DAWs to write and record music. They were familiar with standard producing techniques.

The data from the experiment was captured through a group interview where audio was recorded and transcribed to be analyzed. Observations of the experiment were written down. The group interview was conducted immediately after testing to obtain feedback from the participants regarding their experiences with each approach. The data collected were then analyzed using qualitative analysis methods to identify opportunities, constraints, and themes that emerged from the testing, and observations that potentially align with the literature covered in the study.

4.1 Experiment Design

This section provides an overview of the tools available to the participants during the experiment. Each of the three approaches was allocated a time frame of two hours, with a one-hour group interview conducted after testing all approaches, resulting in a total of seven hours of testing.

4.1.1 Participants

Two participants were enlisted with expertise in music technology and are adept at telematic communication. Both participants have background form using digital audio workstations to compose and record music and are well-versed in standard production techniques. Additionally, the participants were already acquainted with each other and had played music together before the study. Both participants were in their late twenties and were recruited from the Department of Musicology at the University of Oslo.

4.1.2 Location

The participants were situated in separate rooms within the same building and were permitted to interact with each other during inter-session periods. When conducting experimentation, the participants were not permitted to communicate via any means other than through online communication tools.

4.1.3 Equipment

Software

The software used for the experiment was Bandlab, Reaper[1] and LISTENTO. Bandlab is an online platform for creating and sharing music. There is support for real-time collaboration and a social network for sharing creations. The music creation software is basic but fulfills basic needs for recording and editing audio. It can not support higher-level complexity audio editing and recording, and can only supports a total of 16 tracks simultaneously[2]. Reaper supports most functions and features expected in a modern DAW, and has no native support for collaboration. To transfer real-time audio between the users, LISTENTO were used, that integrates within Reaper. The participants used Zoom[3] for communication, with the option to enable video if desired. Only one computer monitor was permitted to be used, to not have Zoom on a separate monitor.

[1] https://www.reaper.fm/ (accessed 13th of May 2023)

[2] Bandlab's features and function is further covered in section 3.2.3

[3] https://zoom.us/ (accessed 10th of May 2023) A video conferencing software that allows screen sharing.

Hardware

The participants used their personal computers for the experiment to make them comfortable and able to use their own plugins and instrument. Both computers were connected through a wired internet connection to ensure stable internet connectivity. They had an external audio interface, headphones, a microphone, and a MIDI controller at their disposal.

4.1.4 Experiment Premises

The participants were asked to create a song in the following environments. Each approach was allocated a time frame of 2 hours.

Approach 1: Controller-Controller: The participants were asked to write and mix a song in Bandlab. No specific roles were assigned to the participants, allowing them to assume whatever roles they found most effective for their collaborative process.

Approach 2: Observer-Controller: One participant was selected as the Controller, and the other as the Observer. The participants used Reaper as their DAW, with audio transmitted through the LISTENTO plugin. The Observer was free to listen to the stream in the browser or as a plugin in a DAW. Screen sharing was done using Zoom. Both participants were free to choose any platform for transferring offline files, including audio and MIDI files

Approach 3: Asynchronous Collaboration: In this approach, both participants used Reaper to put together the mix but were free to use any sound-generating platform to create the audio. Real-time transfer of audio for communicating the sound of the mix or song was prohibited. Instead, the participants were only permitted to exchange audio or MIDI files back and forth using any desired platform for offline file transfer.

4.1.5 Observations

The participants' behaviors and interactions with the approaches and each other were monitored and documented throughout the testing sessions. My role as an observer was maintained throughout each session, and notes were taken to capture the participants' actions and aberrations, playing a non-intrusive role in the sessions and maintaining neutrality while also making themselves available to answer any inquiries about the execution of the approaches. The data collected were later used for analysis to evaluate the approaches' effectiveness with their answers in the group interview.

4.2 Interview Design

Following the completion of the experiments, the participants underwent a group interview, which was audio recorded and transcribed. The primary objective of the interview was to obtain insights into how participants employed different approaches while performing the same task. Participants were encouraged to express their thoughts and ideas freely. The following questions guided the interview:

- Approach 1 (Controller-Controller):
    1. How was the experience of collaborating in real-time?
    2. Did you encounter any challenges or difficulties working this way? If so, what were they?
    3. How did collaboration in real-time affect the decisions made in the process? Describe how you worked on ideas.
- Approach 2: (Controller-Observer)
    1. How did you feel about taking on the role of either observer or controller in this collaboration approach?
    2. Did you encounter any challenges or difficulties working this way? If so, what were they?
    3. Did you feel that this approach allowed you to focus more closely on particular aspects of the project than other approaches? If so, why do you think that was?
- Approach 3: Asynchronous Collaboration
    1. How did you feel about working asynchronously on the project, with each participant working in their own DAW and sharing stems with each other?
    2. Did you encounter any challenges or difficulties working way? If so, what were they?
    3. Did you feel that working asynchronously gave you more time and space to think creatively than other approaches? If so, why do you think that was?
    4. What tools or features did you use to collaborate in this way, and were there any that you found particularly helpful or challenging to use?
- What obstacles and opportunities do you see with the three different approaches? Were there any specific moments of interaction that stood out particularly positive or negative?
- Which of the three approaches do you find the most effective for songwriting or audio work? Why do you think that is?
- When editing and mixing the song, were there any confusions over what parts of the song you were talking about?

- Can you describe the dynamic between you in each of the thee approaches?
- Do you think remote production will be beneficial for you in the future? If so, how?
- Recording
  - Were your projects mainly grid-based or slip-based?
  - When you recorded your instrument, was it easy to synchronize with your collaborators instrument, or the time signature of the project(in terms of micro-timing, grid, start and endpoint)? Describe how you did it.
- Editing
  - Were there any features or functions you found lacking when editing? The question applies to both participants' view.
- Communication
  - How did you find the communication between each of you?
  - Did you use chat to communicate at any point? If so, how?
  - How much of an impact did video communication contribute to the session?
  - Did you encounter any miscommunication? If so, how did this impact the session?

4.3 Summary

This chapter explains the methods used to examine approaches of Remote Music Collaboration Systems (RMCS) in the context of songwriting and mixing. Two participants with expertise in music technology and telematic communication were involved in testing three different approaches to remote music collaboration. The experiment was designed to provoke each approach's constraints, opportunities, and impact, aiming to adapt them into workflows for producers and songwriters. The results are presented as a qualitative analysis in the next chapter of the study. The interview data and observations are then discussed in the study's last chapter in context with previous findings of the study.

Chapter 5

Results

In this chapter, the results from the group interview are presented, together with a discussion.

5.1 Experiment Observations

When using the *Controller-Controller* approach, the participants were excited about using Bandlab as a tool. They had lots of energy and found new ideas quite quickly. In the *Controller-Observer* approach, the *Observer* interacted less with the session. However, both participants were eager to create and communicated a lot with each other. In the *Asynchronous* approach, the communication was at a minimum. There was a significant waiting period between each participant finishing their work, and for the sessions' upload, download, and session synchronization to be finished. Both participants did not encounter any significant technical difficulties, and assistance was at a minimum.

The spatial separation of the experimental conditions was noted as a factor that could impact the results. The participants had breaks together and interacted with each other during inter-session periods, which appeared to facilitate a reset of their cognitive states between sessions. Participants reported feeling more fatigued during the final session compared to the initial session, which can influence the results, as that was the most challenging approach.

Observations indicate that a significantly greater number of ideas were shared when participants could view and listen to the session in real-time. In contrast, the Asynchronous Approach required more attention to planning and session structure, which the participants expressed dissatisfaction with as they did not have a pre-planned song to record and produce. The participants expressed a desire for more creativity and exchange of ideas, which was not fully realized in the Asynchronous Approach. It's suggested that the Asynchronous Approach may be better suited for projects that involve production in stages rather than as a means of exchanging ideas in an environment where real-time communication happens.

5.2 Group Interview Answers

The participants found all approaches suitable for exchanging ideas and to create a song. The main feedback with the Controller-Controller approach was that Bandlab lacked higher level complexity but was suitable for working with software instruments and simple editing. However, as the participants pointed out, Bandlab serves a function that is not seen in traditional studio workflow, where usually only one participant is in charge of a session. The Controller-Observer was perceived as similar to working in recording studios or over a shared computer, where one is in charge, and the other is observing or giving feedback. Participant Two noted, "..the first approach [Controller-Controller], would have been just as easy as sitting in the same room, and I don't think being in the same room for the other approaches would have made it easier because the problems there were more just getting data back and forward....I don't think the spatial distance would have affected the difficulty of collaborating". It is clear that a Controller-Controller environment eased the transfer of audio back and forth from the participants and facilitated a workflow that has not been perceived in physical settings. This indicates a novelty in the design of Bandlab that can open up new doors to other DAWs.

5.2.1 Controller-Controller (CC)

The participants did not find the latency or buffering a problem, but they experienced glitches when using Bandlab. For example, when refreshing or loading the project, sometimes all of the work disappears. They managed to recover it by closing the tab or browser. Participant One perceived Bandlab with "fewer glitches than expected" and a " positive experience". Both participants noted that working in the same space made their communication of ideas clear, as both participants could respond to specific parts of the project. This enhanced their development of new ideas instead of an "upload-respond-revise" workflow, where feedback is delayed.

They found it confusing that *transport-controls*[1] were personal, but *soloing*[2] of tracks was global. Reporting that a *section-based workflow*[3] would benefit their work since both participants can listen to the whole project or mix if needed but work in separate areas. In terms of features and functions in a basic songwriting environment, they found that Bandlab had enough features for the task. However, to work with higher complexity tasks such as mixing and mastering, they found it not suiting as the software was not precise enough and lacked support for hosting plugins.

[1]The controls over playback and record of a session.
[2]Listening to an individual track of a multitrack recording.
[3]Giving one collaborator privilege, or rule over a section of the mix.

The participants also noted that the Controller-Controller approach eased many of the difficulties they had with the other approaches. Both participants contributed on the same premises, thereby, the same tools, workspace, and project layout. Reportedly, they found this approach more "bold" when something needed to be done, as both participants had equal power over the mix. Participant One notes that they acted bold "if we wanted something done" indicating that they established a anarchy over the project. As observed, they deleted each other's parts when they were unhappy or transformed it into something they liked better. Both participants noted that the Controller-Controller approach was perceived "the most collaborative".

5.2.2 Controller-Observer (CO)

The Controller-Observer approach needed one participant to be the *Controller* and one to be the *Observer*. Participant Two had the most extensive plugin- and virtual instrument library and was chosen as the Controller. That was also the participant with the most powerful computer. The Observer found themselves as more of an artist generating ideas, and the Controller as an arranger of the Observer's ideas. They primarily transferred MIDI files between each other instead of audio clips. This was done due to retaining editing compatibility on each participant's side.

Participant Two noted that it was "the software leading the music instead of the people leading the music, which was more in the first one [Controller-Controller]", indicating that if available, they would have used a Controller-Controller approach, as it retained more of the collaborative aspect of the task. Participant Two continued, "even if they are trying not to, they [the Controller] have more of an influence on how things turn out because they can just quickly change things... ...The roles became almost a lot more defined just because I [as the Controller] could easily shove stuff around". The Controller-Observer made implications on how they structured the collaboration. Since one participant is in control and the other has no editorial powers, they are forced to facilitate role division. Participant One found that observing the session made them see the whole picture instead of focusing on individual sections of the song, consequently making it less experimental as they did not have the same experimental control over the session.

5.2.3 Asynchronous Collaboration (AC)

The participants found the Asynchronous Approach the least favorite of the three, reportedly with less "joy" working in a songwriting environment, compared to the other approaches. Participant One noted, "I think it just took a while, even in general, just to find a workflow because this was the least clearly defined workflow". The collaborative aspect diminished since there were fewer momentary interactions and reactions to the material produced. They found little joy in creating new stems and reported that they would instead use the approach with a project in the ending phase.

Participant One said that he found it a bit confusing since they defaulted back to the Controller-Observer Approach, where one were arranging the material, and the other were creating material, even though there was no real-time transfer of project-audio or project-video between the participants.

Participant Two found it very "sequential". He found it not creative enough, as it lacked the exploratory features found in the other approaches, noting:

> "I can imagine if you if you have a very clear concept of what you want the song to be, then this works a lot better. And it is the same as kind of writing a book or something that if we both know what the book is and wants to be, then I can write a chapter, and you can write the next chapter...when we are both trying to work at the same time, and we do not have a clear concept, then it just doesn't work"

As noted by Participant One, they "did not talk about parts of the song", indicating limited communication between them. If the approach had an integrated way of transferring files back and forth, this could have helped them[4]. Revision of files also took a long time since the revised track had to be resent back and fourth between the participants to check the changes, as there was no real-time project-audio transmitted.

5.2.4 Recording

The participants said that a recording environment would be challenging, since in reality, they are working asynchronously from each other. They found that layering tracks [5] were the most efficient. They found all approaches most useful as a production-environment rather than a recording environment. As both participants are familiar with netowrk music performances, they noted that problems and question about recording were more related to telematic communication problems (as discussed in section 3.3.3). When transferring recorded material *offline*[6], they had no issues aligning the recordings, as all of their projects were *grid-based*[7]. The participants recorded musical input mainly through sofrware instruments, which eased the transfer of material between them as file size was smaller. This made transforming of project tempo and notes significantly easier when working in the Controller-Observer and Asynchronous approaches as MIDI is a dynamic offline protocol.

[4]For example Satellite Studios as mentioned in section 3.3.1

[5]Creating one track at a time, and expanding an idea on the basis of that

[6]Non-liner states. For example file transfer of a recorded material.

[7]Projects aligned by bars, beats, and a tempo. The opposite is slip-based, where no markings are present, and typically used in non-rythmical music recordings.

5.2.5 Editing

In a short songwriting setting, the participants miss having their own plugins in the Controller-Controller environment. They would not have used the current state of Bandlab for end-to-end production of a song. The idea of both participants editing in real-time within the same collaborative space was appealing, as edits could be discussed in detail, and changed by both collaborators. It contrasts how traditional studio workflow is arranged since traditional DAW design is arranged for one person and not several creators.

5.2.6 Communication

Regarding the frequency of communication, the Asynchronous Approach involved the least amount of communication. The Controller-Controller approach involved the most communication, as the participants were enabled to work together. The Controller-Observer approach was more limited, with Participant One, as the Observer defaulting into a passive role. The use of video communication reported to not be helpful during the experimentation, as Participant One found that it slowed down their computer. With both participants being familiar to each other, the facial expression were reportedly not necessary to be interpreted. As for miscommunication, in the Asynchronous Approach both participants prevented it by minimizing verbal communication. Miscommunication was less common in the Controller-Controller and Controller-Observer approaches, as both participants had more leverage to participate in the session.

5.2.7 Role Division

In the Controller-Controller approach, both participants contributed equally and communicated effectively. They perceived the Controller-Controller approach as a democratic environment. Compared to the Controller-Observer approach, Participant Two noted that roles needed to be more defined due to Participant One being the Controller. In the Asynchronous Approach, Participant Two continued to arrange and handle most of the song because Participant One had more plugins and instruments available on their computer. The participants noted that this approach required more planning to execute well than the collaborative songwriting environment they were asked to work in. This could have been solved by asking the participants to produce a specific song, or material inn all of the approaches.

Chapter 6

Discussion

In this chapter, the study's findings are discussed, continued with a conclusion answering the two research questions and potential future research.

6.1 Dependencies in Virtual Environments

Both Olson and Olson (2000) and Spilker (2012) suggests that virtual environments does not replace a physical meetup. The participants of this study suggest that the Asynchronous and Controller-Observer approaches do not constitute as large of a difference in their workflow compared to how they would have done it physically in the same room. This aligns with what Hracs et al. (2016) discusses, with a location-agnostic approach to music production making it more accessible. Reliving the boundaries between a virtual environment and a physical environment, can provoke new modes of hybrid platforms such as Bandlab; The Controller-Controller environment discussed in this study does not emulate or imitate workflows seen in desktop platforms for music creation. If the platformization of workflows into online environments also can support a collaborative DAW, it would create a new dichotomy of how music is collaborated by supplying a collaborative environment regardless of the platform actually being used for this purpose. The collaborative function can be seen more as an add-on, rather than the primary function, breaking barriers between virtual and physical environments.

The informal interactions was not measured in this study, as the participants were free to interact in-between sessions. But its clear from this study that the participants found it just as enjoyable working remotely as physical presence. This can also be of affect from their knowledge and confidence in remote environments, but it can also be the nature of the Controller-Controller approach, which incorporates both individual *and* collective presence.

The Asynchronous- and Controller-Observer approaches does not display the same level of collaborative emergence as the Controller-Controller approach, which offers a more democratic environment than the other approaches. Roles has to be more defined to effectively collaborate in

a delayed-feedback collaboration. It is clear that all approaches function as pre-distribution networks, before the finalization of a project. Both the Asynchronous and Controller-Observer approach function best before, and after the main part of the project to either initialize ideas, or to finalize them. However, to create the actual content of a project, a Controller-Controller environment is best suited, given equal participation from both collaborators is needed. The motivation to initiate remote collaboration, is determined by how engaging contributes are willing to be in the project. As shown both from the experiment and the contemporary state of collaboration platforms, they function on separate terms where it may be easier for some creators to neglect the real-time and synchronous aspect of the collaboration, to rather collaborate in a delayed-feedback environment. This can potentially ease the scariness of begive themselves into a remote collaboration. Bandlab is one example of a platform that both supports Asynchronous collaboration tools in their social network, where the same material later can be edited in a Controller-Controller environment. This hybrid may function as a ice-breaker for collaborators that would rather collaborate in a physical environments.

6.2 Collaboration Approaches vs. DAW Affordance

The present study highlights an interesting dichotomy within DAWs, where certain DAWs are better suited to facilitate specific modes of collaboration than others. This finding can be attributed to the inherent design and functionality of the different types of DAWs. The Controller-Controller platforms presented in this study position themselves as Amateur- and Artist-Centric types. They are opposed to Mix-Centric workstations which can be easily adapted for Controller-Observer or Asynchronous collaboration approaches. Mix-Centric DAWs are characterized by a greater emphasis on ensuring reliability, consistency, and standardization. These dependencies, rather than enhancing the creative process, contrast Amateur-Centric and Artist-Centric DAWs, which are designed to a more user-friendly, flexible, and conducive to experimentation and improvisation, which is also the feedback seen in the Controller-Controller approach.

Even though there is a lack of Mix-Centric DAWs that support Controller-Controller approaches, it is essential to note that the transition to a Controller-Controller environment may not be an easy or immediate one. The reliance on reliability and consistency in Mix-Centric DAWs means that it will take time to establish the necessary dependencies to create a reliable system for Controller-Controller collaboration. However, as more musicians and music producers begin to recognize the benefits of this mode of collaboration, we may expect to see a gradual shift towards more user-friendly and flexible DAWs better suited to facilitating new ways of collaborating.

Nevertheless, the need for a Controller-Controller environment in Mix-Centric DAWs must also be discussed, as the dependencies in those platforms are not the same as Artist-Centric or Amateur-Centric

workstations. A mix- or mastering engineer may not need the same modes of collaboration, with equal participation from others in the process. Therefor a "poducer-artist" setting would be more suiting to compare with, as the "producer" in this setting is the mix- or mastering engineer, and the "artist" is the client, defined in this study as Controller-Observer approach to remote collaboration.

6.3 Conclusion

The hypothesises from the research questions were that one approach is not enough to facilitate end-to-end collaboration, as it depends on situation, user, task, and product desired. Existing platforms have affordances that can not be fully adapted to all of the approaches outlined in the study, as producers, artists and technicians all present different needs to conduct remote collaboration.

The results presented in this study suggests a division in remote collaboration software that facilitate remote production of music. All approaches facilitate collaboration in their own ways, and can be used in a production, to varying degrees. Bandlab and Soundtrap as Controller-Controller environments are useful in pre-production environments, or creative stages of a production, but not as an endpoint to release professional sounding music. Mix-Centric workstations as Logic Pro and Pro Tools does not support Controller-Controller environments, and therefor have to use Controller-Observer- or Asynchronous approaches towards online collaboration. Dependencies and usage of those platforms may not even need a Controller-Controller environment, as the work conducted in those platforms may not need equal interaction from all collaborators. Even though the evaluation of the proposed categorizations in this study was not the goal, the categorization of affordance in DAWs and approaches towards remote collaboration can function as a framework to explain these problems in digital audio workstations and remote music collaboration systems. The approaches outlined for remote collaboration can be used to define other remote collaborative environments, not just related to production of music.

6.4 Future Research

Individuals from younger generations who have grown up using the internet for communication, collaboration, and learning may have an advantage over those who have had to adapt their workflows to a digital format. The recognition of latency in digital communication could have a significant impact on streamlining workflows. Although there is no academic literature that specifically explores the effects of this phenomenon, the trend towards an increasingly digital way of life makes this transition more manageable. During this study, participants remarked that they had not previously utilized a DAW that allowed for "Controller-Controller" interaction, which could potentially become the standard for

novice creators using these platforms, resulting in a broader acceptance of this design as the norm in generations that are "internet-natives". The field of online democratic DAW is little researched, and can open up a lot of interesting views of how music is being co-produced in the future.

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