July 25, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 405W Project Proposal for the **Sheet Music Transcriber** by **HappyJam**

Dear Dr. Scratchley,

As per the ENSC 405W Capstone A course Instructions, please find attached to this letter the project proposal for the SMT (Sheet Music Transcriber) by HappyJam. The SMT takes in an audio sample of music played on any instrument or a small group of instruments and converts the music to a score ready to be played or further edited by a musician.

The document attached below will provide an overview of the Sheet Music Transcriber (SMT). It provides background information about the SMT and then discusses the scope of the SMT while outlining the risks and benefits associated with the project. We provide our research related to market and competition and how we aim to out do our competition with our features. It is followed by an estimated budget and costs associated with developing the SMT. We conclude with providing a schedule for the implementation of SMT and milestones achieved till date.

HappyJam is a multinational, diverse, and multidisciplinary team of passionate senior engineering students: Computer Engineers Matthew Marinets, Polina Bychkova, Haoran Hu, and Avital Vetshchaizer; System Engineer Jaskirat Arora; and Electronics Engineer Akaash Parajulee.

Thank you very much for your time and consideration. We truly appreciate your concern and time investment. Please let us know if you have any questions or concerns. You could contact our Chief Communications Officer Polina Bychkova anytime at pbychkov@sfu.ca.

Regards,

Matthew Marinets
Chief Executive Officer
HappyJam

Project Proposal for The Sheet Music Transcriber

The Sheet Music Transcriber by HappyJam

Company 1

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Executive Summary

Musicians train to play music from score and create music with their instruments. To master any instrument it requires skill and a lot of time investment. Despite the time and skill needed to play music from its score it is easier than creating a score from listening to music (called transcribing). This requires repetitive listening, trial and error and intensive training. Not everyone who wants to learn to create new music wants to go through the complex process of learning music transcription. There is a huge market for softwares that can assist in music transcription. Not only professional music transcribers are in need of such softwares but beginners who are starting to play, music teachers who need to teach it, freelancers, etc. all benefit from it. The Sheet Music Transcriber by HappyJam is designed to cater to this sector of the market.

The Sheet Music Transcriber (SMT) is a program that eases the transcription process by automating the transcription process, generating scores from audio recordings and providing visualizations for the different stages of analysis. The Sheet Music Transcriber consists of three components: The algorithmic System, The State Manager and the User Interface.

The algorithmic system identifies notes and musical properties such as tempo and time signature.The state manager governs how data is organized and passed between the algorithmic system and the user interface, maintains state, and saves project setting and progress to disk. The user interface includes all data input and visualization methods in the SMT, including audio spectrogram display, data display, and algorithm parameter input methods.

The number of freelancers, amateur artists, music teachers, aspiring musicians outweigh the number of trained music transcribing professionals in the world. [A2] There are softwares that assist in transcribing music but due to their limited utility and costs associated with getting access to them limits the learning curve of music transcription. We at HappyJam aim to outdo our competition by developing an Open Source Software that helps in the process of music transcription while making it interactive and learning for new musicians.

HappyJam is very excited to develop Sheet Music Transcriber as an effective solution for converting music or audio files into sheet music. We are a team of five skilled and highly motivated engineering students with experience in playing music, UI development and software development. SMT will improve the experience of converting music into a score and make this process a reality for aspiring and young music enthusiasts.

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Glossary

12TET
Twelve-tone equal temperament. The standard tuning system in modern Western music, organizing pitch into twelve equally-spaced tones in every octave. An octave has a frequency difference of a factor of 2, and hence every tone in a 12TET system will be $\sqrt[12]{2}$ times higher than the next-lowest tone.

Chord
A group of notes played at the same time.

FFT
Fast Fourier Transform — a family of algorithms that quickly calculate a Discrete Fourier Transform by taking advantage of properties of the Fourier Transform and reusing intermediate values.

Harmonic
A component of a periodic signal or waveform at a particular integer multiple of the fundamental frequency. The sinusoidal component with the same frequency as the overall signal is the first harmonic; the component at twice the frequency of the signal the second harmonic; and so on.

Note
The smallest unit of musical analysis. A note is a pulse of sound with a few properties:
- Timing: when the note is played
- Duration: How long the note lasts
- Pitch: the fundamental frequency of the sound
- Volume: the amplitude of the sound
- Timbre: waveform of the sound; timbre varies with instrument

Pitch
Pitch is the name musicians give to the fundamental frequency of a note. Pitches have names that loop through [A, A#, B, C, C#, D, D#, E, F, F#, G, G#], sometimes notated with a number following the pitch symbol to indicate which octave it falls in. Pitch names are spaced logarithmically, so A4 (440 Hz) is twice as high as A3 an octave below (220 Hz).

POI
Point of Interest. Refers to locations in the spectrogram that may represent part of a note or a harmonic of a note.

Score
A score is a document written in sheet music that describes how to play a song.

Sheet Music
Sheet music is the primary notation used in Western music to describe how to play a particular part or song.

Spectrogram
A two-dimensional image acquired from an audio sample representing the relative power carried by across time and frequency axes.

Transcription
The process of writing down music in sheet music notation.

Timbre
Timbre is the quality of a note that differs between instruments, manifesting physically as a different waveform. As the wave is periodic, timbre may be described as the relative power of a note's harmonics — that is, the relative power present in frequencies around integer multiples of the fundamental frequency.

Tempo
The speed by which a section of the music is played, expressed in beats per minute (bpm).

1. Introduction

Musicians are trained to create music with their instruments, and often use sheet music as a written method of recording and communicating musical information. Performing a piece of music from its score is generally a straightforward task and can be done in real-time by a skilled performer. Converting information the other way, transcribing music into a score, is much more difficult. This process requires repeated listening, trial and error, and specialized training.

The Sheet Music Transcriber (SMT) is a program that eases the transcription process by automation and visualization, generating scores from audio recordings and providing displays of the different stages of analysis.

This document gives a high-level overview of the design of the SMT, as well as analysis of the current market and competition, cost considerations, and the current plan of the development timeline.

2. Project Overview

2.1 Background

Analyzing audio, particularly pitch changes over time as we are doing with the SMT, falls in the domain of time-frequency analysis. The most basic tool in this field is the spectrogram, constructed from the Short-Time Fourier Transform (STFT). A Fourier Transform takes a series of time-domain samples and converts them to the frequency domain, displaying which frequencies make up the series. A Short-Time Fourier Transform involves looking at a continuous subset of the audio samples to obtain a Fourier Transform of a localized region in time. By taking consecutive STFTs of an audio sample and lining up the resulting spectra next to each other, we can generate a two dimensional image representing the power of specific frequencies at specific times. This is a spectrogram — one axis of the image represents frequency, one axis represents time, and the value of a certain pixel represents the power of a given frequency at a given time.

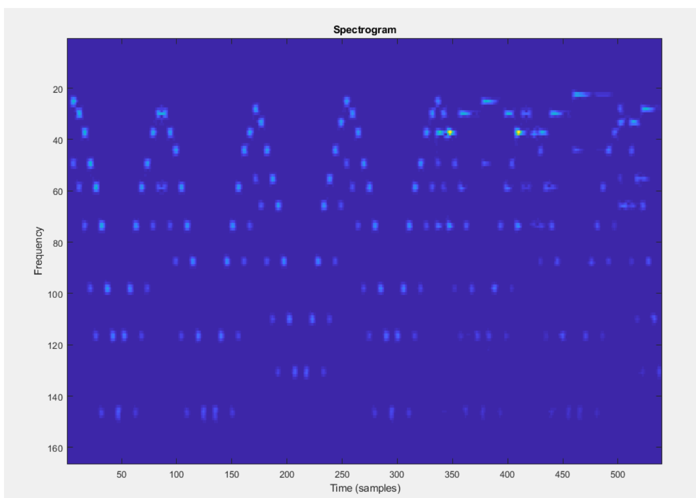

Figure 2.1.1 — An example of a spectrogram, taken of the first few seconds from the Track 1 Theme from the Top Gear (SNES) OST

When analyzing audio, there are generally two kinds of sound we wish to identify and distinguish, referred to here as pitched and percussive sounds. Pitched sounds have a periodic waveform with a fundamental frequency representing the slowest frequency of the sound. As periodic sounds can be entirely described by a Fourier Series, the Fourier Transform of these sounds looks like a series of narrow peaks at the fundamental frequency and integer multiples of the fundamental frequency, with relative heights proportional to the Fourier Series coefficients. Such sounds appear within a spectrogram as a series of peaks occurring at the same time but spread out across the frequency range. The lowest-frequency peak is the fundamental, and the higher peaks are called overtones. Pitched sounds are those that might be made by a piano, violin, saxophone, or any instrument that can play many different pitches.

Percussive sounds, on the other hand, do not have a fundamental frequency. As the name implies, these are sounds made by drums, cymbals, impacts, or any kind of percussion. Within a spectrogram, these sounds show up as continuous high-power regions running down a large portion frequency axis, though the precise amplitude of these pixels can vary quite widely. Different percussion instruments, such as tombs, snare drums, crash cymbals, or high-hats, will generally occupy different frequency regions.

These tools and observations turn the challenge of note identification into one of image feature identification within a spectrogram image. By using thresholding, peakfinding, connected region identification, and primitive presence detection, we can identify various musical features present in the audio.

2.2 Scope

The primary goal of the SMT is to:

- Display a spectrogram of input audio
- Identify points of interest (POI) within the spectrogram, and
- Compile that information into a more musician-friendly form

Points of interest are not the same as musical notes — POIs may contain a fundamental frequency and all of the overtones of a note, where musicians are generally only concerned with the pitch of the fundamental and the instrument that generates the correct overtone series.

For the first prototype, the SMT will simply filter out these overtones and display only notes identified from fundamentals. Later versions will use the relative power of the overtones to generate a timbral fingerprint of the instruments in the audio — that is, it will generate a likely list of overtone series that best accounts for the POIs found within the spectrogram. Using this fingerprint, notes may be organized into classes that will roughly reflect the instrument that played them.

Once notes are identified, the first prototype will simply display them as a piano roll. Later versions of the SMT will also be able to display this information as a musical score or export this information as a MIDI file — a standardized format for electronically communicating what notes are played at what times.

The SMT will not concern itself with vocals or speech identification. While notes may be classed by their overtone series, any label attached to a given timbral fingerprint must be provided by the user. This will hopefully allow the SMT to remain useful even when analyzing audio containing new or unusual instruments, such as in electronic music or music from cultures that don't make it into many audio machine-learning databases.

2.3 System Overview

The SMT (Sheet Music Transcriber) created by HappyJam aims to be an assistant for musicians of all levels. Our tool will be able to detect notes played within an audio sample and determine their properties, such as duration, volume, pitch, and timbre. It may then display the result as sheet music or a piano roll for a musician to begin practicing with. It may also export this result as MIDI or a MusicXML file for a musician to further edit, clean up, or re-use the result. This simplifies the process of transcription so that even a beginner may begin working with it. When applied in real-time situations, the SMT can even assist learners and teachers, giving them another view into what they're playing.

The SMT has three main subsystems to be designed: the algorithmic system, the state manager, and the user interface.

The algorithmic system identifies notes and musical properties such as tempo and time signature. It includes several input parameters which the user may adjust to fine-tune note detection and identification.

The state manager governs how data is organized and passed between the algorithmic system and the user interface, maintains state, and saves project setting and progress to disk. To allow for easier algorithm development and user modification, the system architecture must be able to dynamically load different algorithms and input parameter sets, and update the UI and intermediate data in storage to match.

The user interface includes all data input and visualization methods in the SMT, including audio spectrogram display, data display, and algorithm parameter input methods.

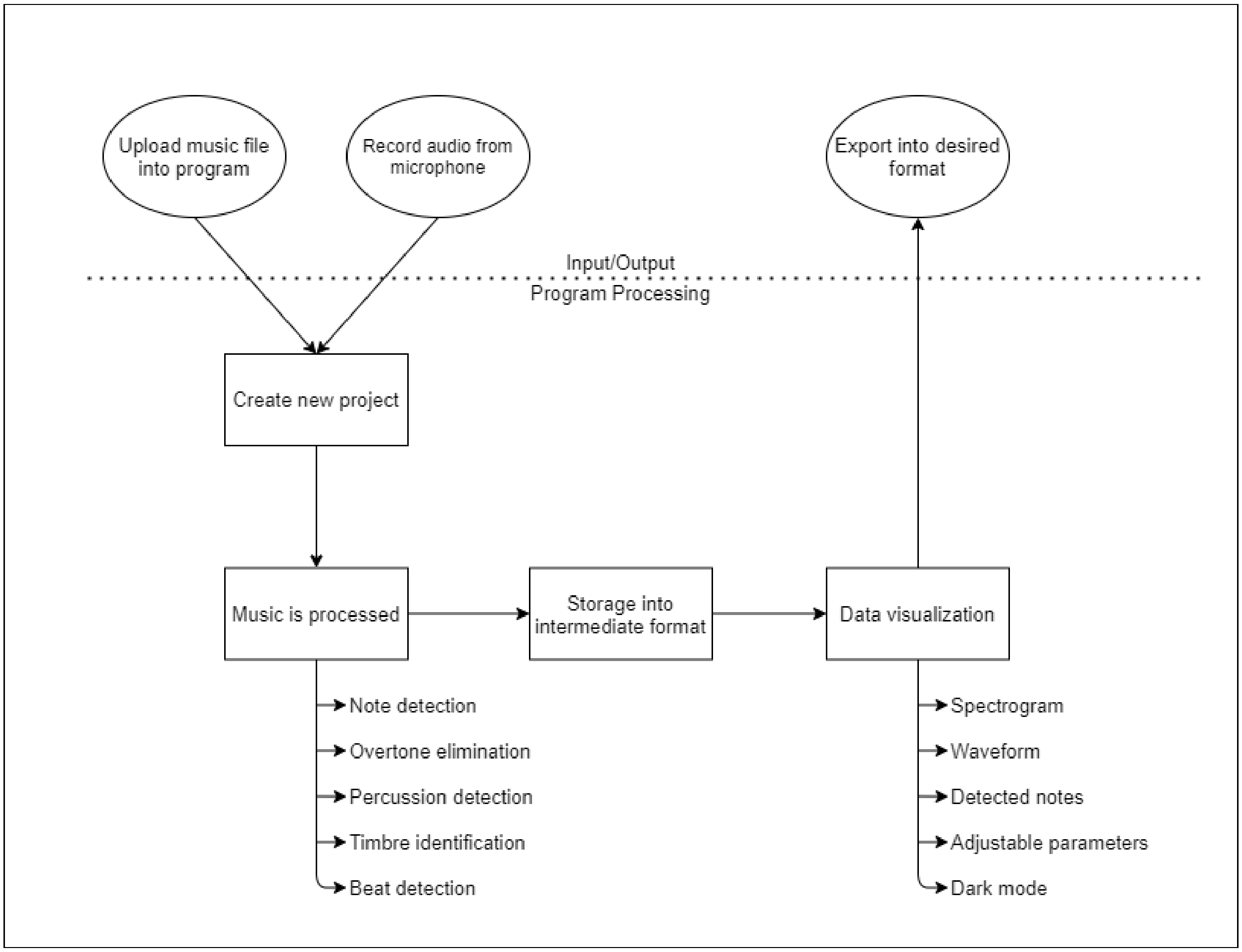

Figure 2.3.1 — An information flow diagram of what the SMT should accomplish

2.4 Risks

When installing new software onto a computer, there are inherent risks for a user from the user. Among these risks, the most relevant to the SMT are active processor consumption, idle processor consumption, and security vulnerabilities caused by the software.

In the running and utilization of the program, the processing power required by a program often needs to be considered. When it comes to most programs, their functionalities usually don't entail any processor or graphics unit heavy actions. However, with the SMT, in the processing of the music files the algorithms acting upon those files can be processor intensive. If a user's hardware is not sufficiently powerful, or the program designed to process too much at once, this can lead to the program slowing down or even freezing a user's computer. In the worst case scenario, a user will have to forcefully shut off their computer in order to regain access to their computer. As such, steps will be taken in order to ensure the SMT does not overload a user's system, and does not consume too much processing power.

While the program is running, a user may have to simultaneously run other programs in the background. For example, a user might want to listen to multiple music files in a music listening program and choose the appropriate one, or might be multitasking. While this is occurring it is necessary to ensure that the processing power required for the program to be idle is low enough to handle these functions, otherwise the risks associated with active use of the program may exhibit themselves while the program is simply idling.

The capabilities of this program and access it has to the system is something that could become a risk for the user as well. If a program has unmitigated access to a system, it could be hijacked and used for harm. As such to prevent such a thing from happening, it is important to ensure that the access the SMT has to a user's system is limited. As such, throughout the process of developing the SMT, the security and safety of a user's system will be paramount and the program will not be allowed the possibility of accessing components of a user's system outside of the specified use cases.

2.5 Benefits

Professional Musicians
The Music Transcriber will allow musicians to gain a deeper and more detailed dive into their melody. WIth each session, The Music Transcriber will showcase a detailed breakdown of the melody, including all the chords, notes, timbre, and duration it finds.

Beginner Musicians
Having the ability to dive into the world of music with the assistance of The Music Transcriber will allow the beginners to gain confidence in playing and reading music sheets. Beginners will also be able to gain increasing interest in the music, once the melody-to-paper aspect has been resolved.

Society
With automated transcription, the Music Transcriber will greatly benefit society by allowing everyday individuals to gain a full understanding of music and assist in transcribing melodies. This will build appreciation for music and inspire the next generation of musicians.

3. Market Analysis

3.1 Global Music Industry Market

The Music Transcriber is a software that is primarily targeted towards intermediate and professional musicians with the ability to manually transcribe music independently. The market analysis will be based upon these factors and will include market analysis, market size, and competitors.

The Music Transcriber allows users to automate the transcription of any given melody played by a select number of instruments. In 2018, the total revenue for the entire global music industry was US$53.77 billion [1]. The music industry is expected to suppress global revenue of US$65 billion by 2023 and continue growing at a rapid pace as streaming popularity continues to grow [1].

Figure 3.1.1 below describes the estimates for the global music revenue market from 2012-2023 [1].

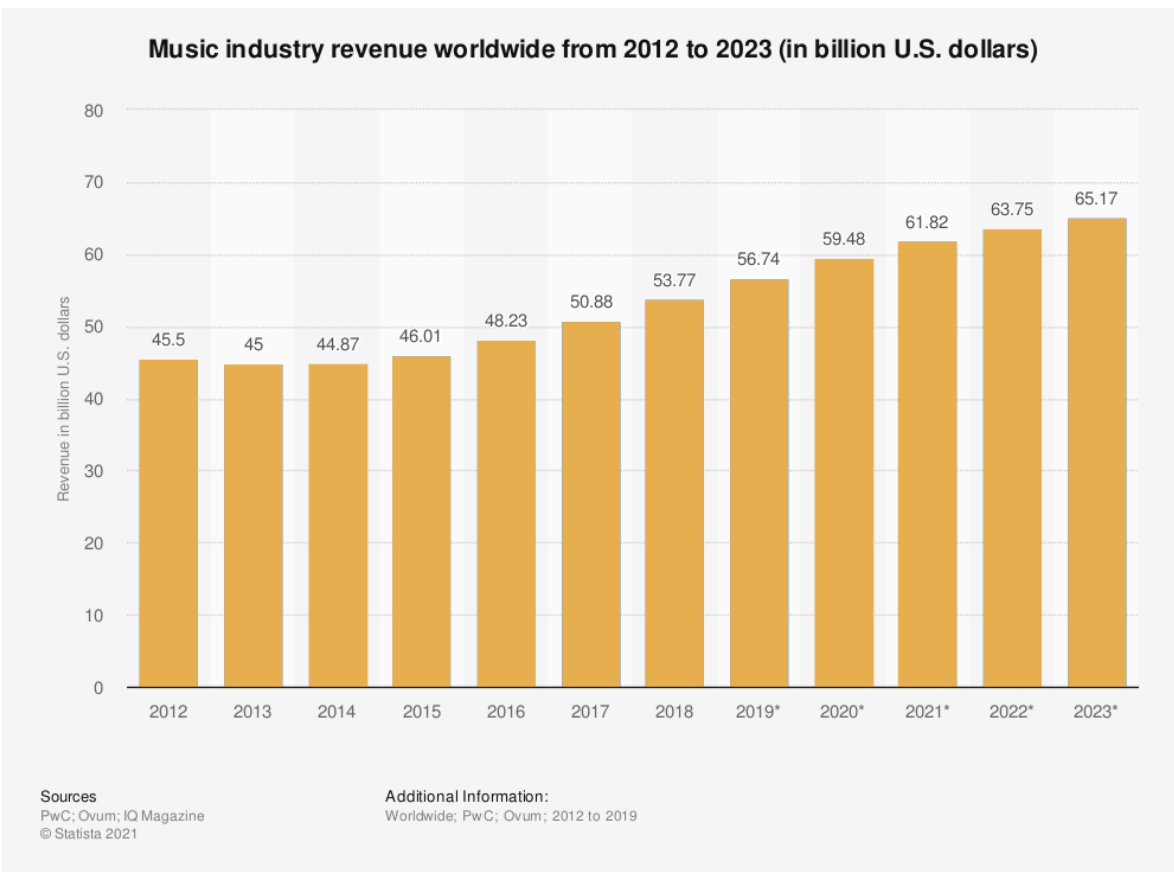

Figure 3.1.1 — Music Industry revenue worldwide from 2012 to 2023

3.2 Market for the Music Transcriber

While there are individual professional music transcribers whose full-time responsibilities are to transcribe melodies, the vast majority of the market is populated with hobbyists, freelancers, and music teachers [2]. As seen in the figure below, there are currently estimated 122,500 music teachers around the US, and over 10 million worldwide [2].

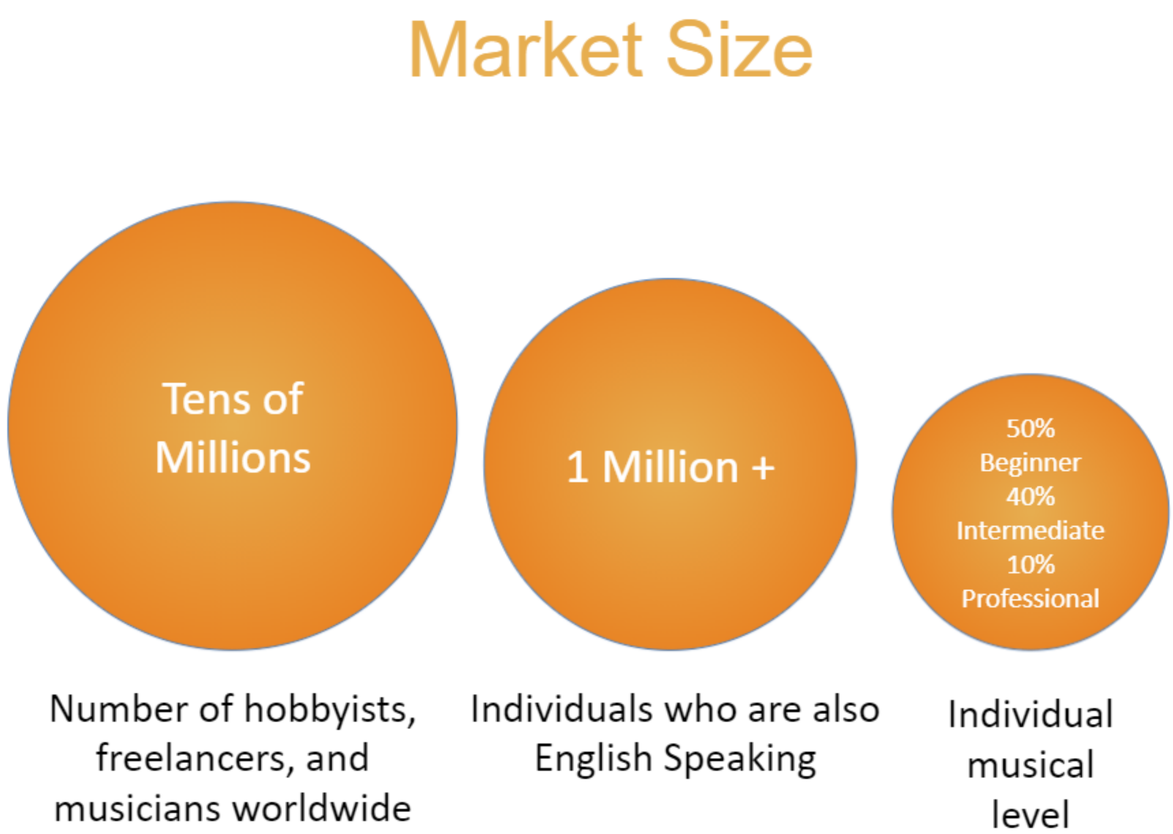

Figure 3.2.1 — Market Size [2]

For each music teacher there are multiple students whose curiosity is sparked by the different works. As seen in *Figure 3.2.1*, the Music Transcriber has millions of potential customers who are eager to transcribe their own melodies. The music Transcriber will assist the students in saving time and will allow them to focus on the music and the details of the melody, rather than the music-to-paper translation.

3.3 Competition

TranscribeMe is a platform that allows individuals to pay someone with musical skills to transcribe music. The rates on the platform range from $15-$22 per audio hour and requires a manual transcription by an individual.

Figure 3.3.1 — TranscribeMe Logo

Similarly to TranscribeMe, **Upwork** is another platform that allows freelancers to earn income by getting hired to transcribe melodies. The rates vary wildly and once again require manual transcription.

Figure 3.3.2 — Upwork Logo

Possibly our largest competitor is **AnthemScore.** With moderate to average review score, **AnthemScore** is the top music transcriber on the market. It allows a real-time modification of the score, as well as a subjectively usable transcription.

Figure 3.3.3 — AnthemScore Logo

While all these services offer a solution to music transcription, their performance is not perfect and can often be subjective. Below is an a figure to describe HappyJam's standing on the market:

Competition

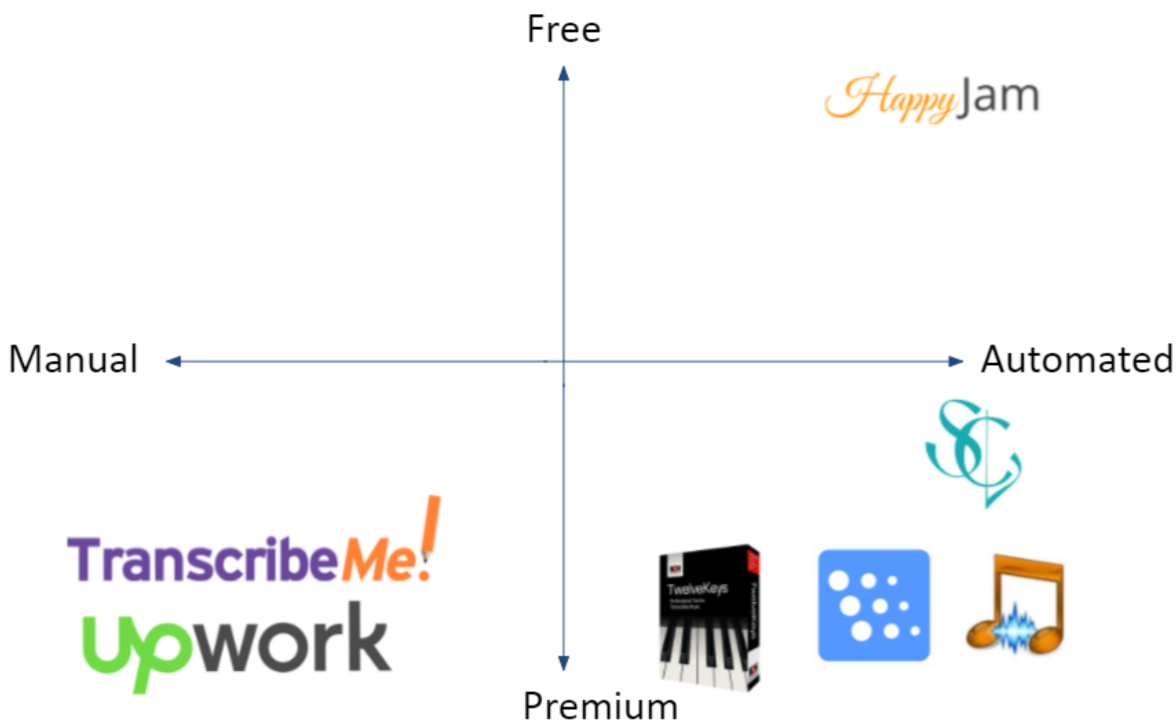

Figure 3.3.4 — Competition Graph

As presented in *Figure 3.3.4* above, HappyJam's The Music Transcriber stands at a unique, vacant part of the market. The Music Transcriber is fully automated from start-to-finish and allows the user to acquire a music sheet within seconds. The Music Transcriber will enable that by supporting an open-source platform that allows individuals to contribute to the algorithm and thus improve the software. This also allows the software to grow in a more stable, yet rapid paste compared to the closed individuals such as *Transcribe!* And *AnthemScore.*

4. Cost Considerations

4.1 Cost Estimate

We plan on having our completed software package to be open-source software, keeping this in mind we were sure to use software that was open-source or free for students to use under SFU student access. Due to this nature of our project there are no cost overheads associated with development of the software.

Our project has no cost at the proof of concept stage since there is no hardware associated with it at this stage. Our final project does come with a microphone recommendation for the users that will be optimum for audio pickup. To get the ideal recording we would be experimenting with different types of microphone with different pick-up patterns. There are 6 essential microphone pick-up patterns [4] that we will be experimenting with.

The *table 4.1.1* below summarizes the costs associated with different types of microphones.

Table 4.1.1 — Cost Estimation for Microphones

Microphone Pick-up Pattern	Estimated Cost (CAD)
Omnidirectional	26 [5]
Cardioid	31 [6]
Hypercardioid	32 [7]
supercardioid	22 [8]
Unidirectional	29 [9]
Total Cost for Microphones	140

**We are aware that there are bidirectional microphones but due to the high costs associated with these microphones we would not be testing these type of microphones with our software

4.2 Funding

For funding of our project we would be aiming for 2 specific funding options namely Engineering Science Student Endowment Fund and Wighton Engineering Development Fund.

4.2.1 Engineering Science Student Endowment Fund

The Engineering Science student Endowment Fund is given to SFU Engineering Science Undergraduate Students working on their projects. The ESSEF is managed by the Engineering Science Student Society (ESSS). Students can apply for this funding at the beginning of the semester they intend to work on their project. This funding has four categories with their specific requirements. A team must meet all requirements of the category they are applying for. The four categories are:

- Category A - Competition
- Category B - Entrepreneurial
- Category C - Class
- Category D- Miscellaneous

We would be applying for Category C of this funding. Our project and team meet all the requirements for this funding option. More information about this funding can be found on ESSS website.

4.2.2 Wighton Engineering Development Fund

The Wighton Engineering Development Fund is managed by Dr. Andrew H. Rawicz. The projects are funded by the Wighton Fund on a competitive basis. Dr. Rawicz along with 2-3 randomly selected faculty members go through all application proposals and fund the successful proposal through a fixed budget. The project proposal that satisfies the Wighton's requirement of practicality the closest is usually selected for funding. The projects that benefit the society are given preferential treatment.

5. Project Planning

HappyJam will be developed in three main phases, with each phase aiming to produce a deliverable milestone that can be demonstrated to the relevant stakeholders. *Table 5.1* below identifies the three major milestones targeted for this project.

Table 5.1 — Milestone phases

Phase	Milestone	Target
A	Alpha	Q3-21
B	Beta	Q4-21
V1	Release	Q1-22

Phase A will be completed throughout ENSC 405W in the Summer 2021 semester. The alpha milestone will focus on the initial proof of concept, setting up the UI framework and establishing algorithms for detecting notes to be displayed. This includes:

- UI for loading and configuring uncompressed audio samples
- Pitch and power detection
- Start and peak of note detection
- Displaying various visualizations of the audio analysis
- Navigating and fine tuning the analysis visualization

This functional prototype A will be carefully implemented, using best practices to be expanded upon in the following phases of development, while allowing room for feedback consideration.

Phase B will be completed in the following semester, during ENSC 440. The prototype will be completed at the end of this stage, which will provide more functionality and capabilities than the previous deliverable. This will include:

- Detecting note duration and general tempo detection
- Relative volume detection
- Timbre distinction and profiling
- Compressed audio and microphone support
- Piano roll and sheet music display including key and time signatures
- Midi and save file export

After Phase B is complete, the release version will focus on fine tuning and extending the configurability of the core features to provide one of the most complete audio transcription experiences on the market. This will include tempo change detection, timbre filtering, built-in note editor, instrument detection and extensive export format support.

Figure 5.2 and *Figure 5.3* below outline the schedule for HappyJam over the first two phases of development.

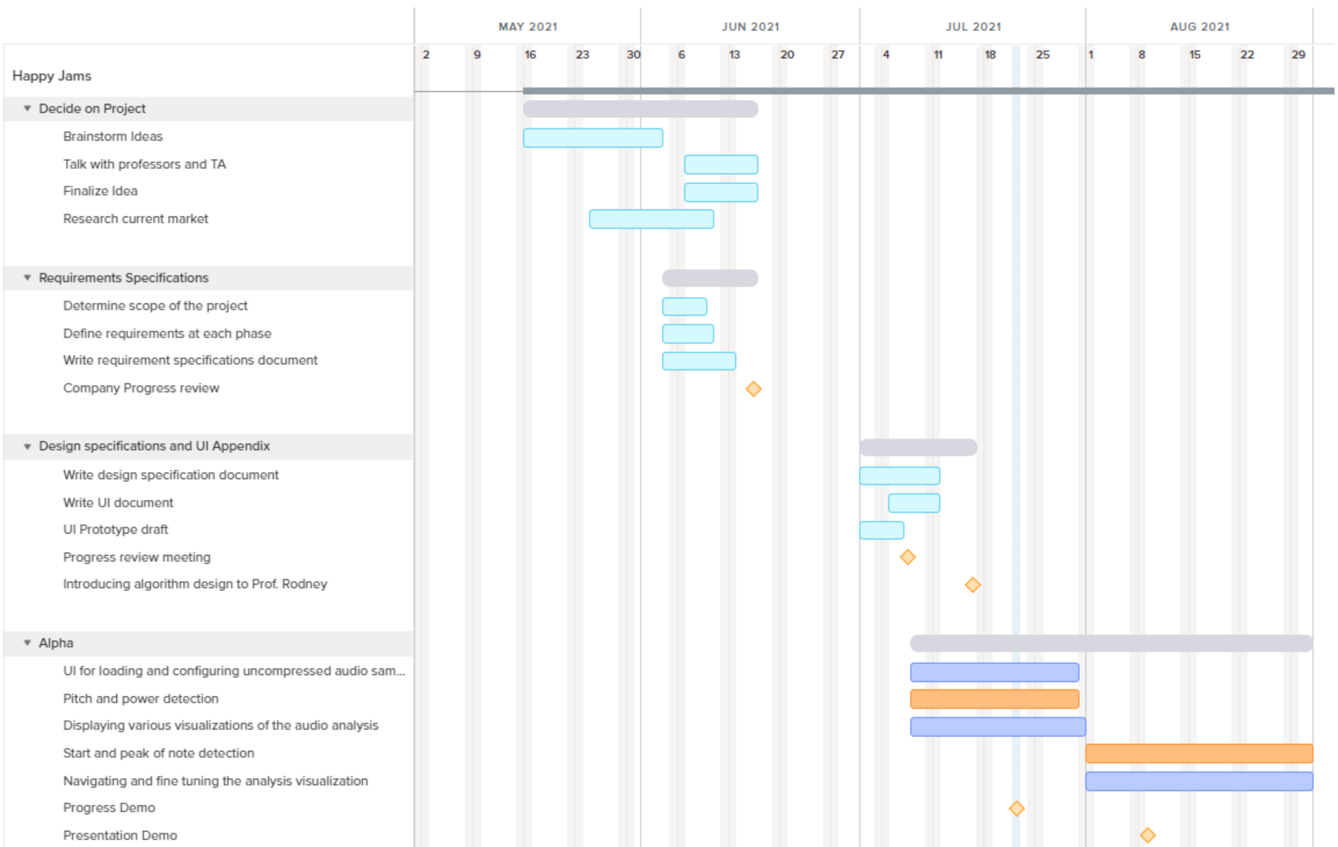

Figure 5.2 — Project planning for Phase A

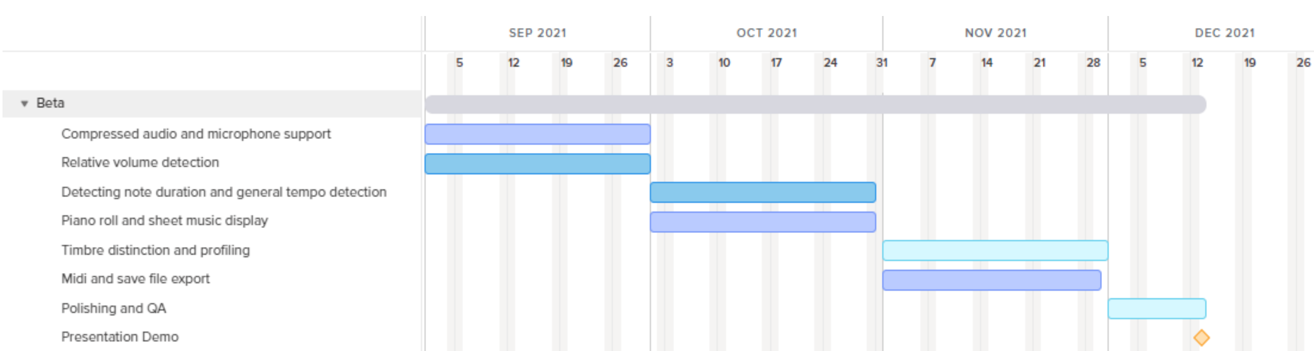

Figure 5.3 — Project Planning for Phase B

6. Company Details

6.1 Matthew Marinets

Matthew is a fifth-year computer engineer with a particular interest in image processing, audio processing, and automation. They have had co-ops at Copperleaf Technologies and Kardium Inc., where they worked on automated systems large and small. Additionally, Matthew has been a musician for over fifteen years, primarily playing piano but with some minor experience on violin and guitar. Leveraging their musical experience, interest in signal processing, and automation experience, Matthew has taken the leading role in developing the algorithms behind the Sheet Music Transcriber.

6.2 Akaash Parajulee

Akaash is a fifth year Electronics Engineering student. Experience in movie lighting, embedded systems, microcontrollers, and Amazon Web Services are some of the areas that Akaash has acquired through his varied co-ops and jobs. Separate from these work related activities, he also played a saxophone over the course of 7 years. From these years of saxophone Akaash has acquired a base knowledge in music, and a taste for boombastic jazz music. Applying his varied experiences and base knowledge in music, he has taken a supporting role in development of the algorithms behind the Sheet Music Transcriber.

6.3 Polina Bychkova

Polina is a passionate computer engineering student with interest in real time systems software and software optimization. She has experience in dev ops, automation, virtualization, 3D imaging. She has taken on the role of implementing UI requirements for invoking the analyses algorithms and presenting the results to the end user and ensuring a satisfying user experience. She has also been entrusted with the role of CCO within the HappyJam company.

6.4 Avital Vetshchaizer

Avital is a fifth year Computer Engineering student passionate about chip design and machine learning. He has experience in web development, mobile development, chip design, and construction of neural networks for machine learning projects. During his two co-ops at TELUS and FORM Swim, Avital took part in the construction and development of multiple web programs related to issue tracking and project maintenance. While not working on engineering projects, Avital enjoys hiking, swimming, and cycling around the beautiful area of Vancouver, BC. Now, Avital is an engineer at HappyJam who works on the algorithm and artificial intelligence aspects.

6.5 Jaskirat Arora

Jaskirat is a fourth year Systems Engineering student with interest in mechanical and circuit design. He has experience with embedded systems and microcontrollers. During his co-op at INEO Solutions Inc, he worked on designing 3D products for customers and configuring the system on modules for their flagship product. During his recreational time Jaskirat enjoys playing shooting and strategy games like Call of Duty, PUBG, World of Warships. He is helping the team with implementing the User Interface requirements and in integrating the algorithms into the UI.

6.6 Haoran Hu

Haoran is a fifth year computer engineering student, who is passionate about software design, robotics. Haoran has worked as kernel developer at previous co-ops and greatly enjoyed the team work and collaborations. In his free time, he likes to play soccer, read books and travel around. Haoran has been taking a role in developing the UI part of the Sheet Music Transcriber.

7. Conclusion

Sheet Music Transcriber is aimed at making the task of music transcription manageable by the vast majority of the population that wants to learn to play and create music without going through the professional training of music transcription. The algorithmic system identifies the notes and tempo of the recording being analysed then passes the analysed data through the state manager that saves, stores and transfers data between the algorithmic system and the UI. The user interface with its visual representations of the recording in the form of audio spectrogram and data display with adjustable parameters makes the task of transcribing interactive. With this software to use the knowledge needed to transcribe music is bridged for new and aspiring musicians.

This document gives a summarized overview of the Sheet Music Transcriber proving the background information, the need and the scope for such a software. It also briefly explains the working and the implementation of the idea of music transcription. The market for music transcription softwares and the competition to SMT has been well researched showing the need for it and how our version of the software is aimed to be better than those available in the market. This document estimates the cost that will be associated with the complete development of our project and proves that making it open source with a microphone recommendation makes it inexpensive to develop for us and for musicians to use.

The engineering team at HappyJam is confident that our product will revolutionize the process of music transcription by making it convenient, hassle free and interactive for its users. Because in the end, music should be fun.

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