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Distributed
Computing

Hip Hop Robot

Semester Project

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Abstract

As a successor to the project Robot Composer Framework, this project is aimed
to generate a specific music genre, namely Hip Hop music, based on the existing
framework. The knowledge used in generating Hip Hop music is based on some
rules of generating Hip Hop beat, as well as some western music theory, which set
the knowledge-base of previous project. This project is implemented in Python
and uses mido and PrettyMIDI library extensions. The generated music is saved
as standard MIDI file. This Hip Hop Robot Composer can generate a Hip Hop
Beat by using a small piece of music as input, this method is called "Sampling"
in music industry. And in the future, the current framework can still be extended
to realize other function.

Contents

Introduction

The goal of this project is to generate a piece of music only according to the music theory, and not using machine learning techniques. In order to realize the goal, Hip Hop music theory has to be researched and the existing framework should be modified to generate music in Hip Hop way.

1.1 Motivation

Hip Hop music is quite a popular music genre in the world now. A perfect Hip Hop song is composed of two essential aspects: fancy lyrics and rhythmic Hip Hop beat. Nowadays, the most popular Hip Hop music is *Trap music* [1]. Trap music is famous for its intensive, sub-divided drum beat and blurry music atmosphere, and the produce of Trap beat is rather a fast process compared to other kind of music. Producer uses a piece of sampled music as input and let it loop over again to form the music background of Hip Hop beat, then Producer adds other layers of music which fits the input track and also adds Hip Hop style drum beat to complete the whole beat.

In this way, to generate a piece of Hip Hop music is quite easy. And it is possible to generate a Hip Hop beat only depends on music theory. With the current Robot Composer framework, we can generate Hip Hop beat with many layers.

1.2 Related Work

This semester project is based on the previous projects of Robot Composer in the distributed computing group.

The first semester project done by Roland Schmid [2] created a program which is able to generate a piece of jazz music randomly, just like a jazz soloist's improvisation. This project used Sonic Pi, a freeware music coding program which can play the music in loop and also modify this loop. This project can generate

some creative jazz music, however, it is hard to write complex program in its programming environment.

The second semester project done by Noah Studach [3] created a robot composer framework by using Python as programming language and MIDIUtil [4] library extension. This project can generate a piece of electronic music with five layer based on a chord progression. This framework has good readability, most functions are clear to understand while start using it. This framework also has good extendability, the process of generating music can be modified and other functions can be added in. The music which is generated by this framework has five tracks, this character fits for generating Hip Hop Beat, which usually has more than four tracks in a single piece. But a problem of this framework is that it can not assign instrument to different track.

Theory

2.1 General MIDI (GM1)

In order to generate music electronically, MIDI has to be used. In "Robot Composer Framework" project[3], MIDI standard has been introduced. However, in order to make music generated sounds correctly in terms of instrument being used on different track, we have to check the General MIDI, which is responsible for assign instrument to each track[5].

2.1.1 General MIDI Features

While generating music using General MIDI, features of General MIDI must be known. Since there also contains some requirements or restrictions in General MIDI features.

- Voices: In terms of ordinary melodic and percussive sounds, a minimum of 24 fully allocated voices are available at the same time. Meanwhile, as for melody plus 8 for percussion, a minimum of 16 allocated voices are available simultaneously.[5]

- Channels: There are in total 16 MIDI Channels which can be used. Each Channel can play a number of voices as well as polyphony. Each channel can also be assigned with one instrument, the voices which the channel plays will be instrument's sound. However, MIDI Channel 10 is a special case. This channel will always play percussion.[5]

- Instruments: There are in total 128 instruments to be chosen in channel 0-9 and 11-16. Each instrument has a program number, which is used for assign instrument to the channel. There are also 47 percussion sound in General MIDI, each note number refer to the sound of one percussion instrument or one part of drum kits. [6]

2.1.2   GM 1 Sound Set

As introduced in the previous part, General MIDI can play sound of various instruments. However, what General MIDI defined for sound of instrument is only the name of sound, rather than how it is reproduced.

The sound of 128 instruments and sound effects are divided into 16 families, in each family there are 8 instruments to choose from. Instrument Family helps user to choose the instrument properly according to the genre or style of music they want to generate.

As for percussion, note number (range from 35 to 81) refers to percussion sound, and each GM-compatible instrument must have sounds whose keys are note numbers for percussion. The way to generate a percussion track is to select a, instrument and assign it to Channel 10. Then instead of playing musical notes, it will play the drum sound which the note number refers to. There are also some instruments can play other sounds when given an note number beyond the range of percussion note numbers. In some occasion, kits which can play various percussion sound can also be selected as percussion instrument. [6]

2.1.3   General MIDI 2

General MIDI 2 is an extended version of General MIDI 1. In General MIDI 2, more sounds of instruments are available and more control to the sound can be operated.

In General MIDI 2 Features, we can see more sounds can be played simultaneously. And General MIDI 2 devices are also compatible for General MIDI 1 devices.[7]

2.2   Hip Hop Music

2.2.1   Brief Introduction

Hip Hop music, also called hip-hop or rap music, is a music genre developed in the United States by inner-city African Americans in the 1970s which consists of a stylized rhythmic music that commonly accompanies rapping, a rhythmic and rhyming speech that is chanted.[8]

The rapping of hip hop music usually has a tight rhythm, because most of the lyrics of hip hop songs are very long. A hip pop song is generally 3 or 4 minutes

long, and the lyrics can be up to nearly a thousand words which requires a very fast speech rate.

The accompaniment part is generally the continuous use of certain fixed tone, and the tonality is more clear. Some tones are soothing, while others are compact, depending on the content of the song. Usually, accompaniment will use more powerful music types, and to make it more contagious, it will add some vocals or machine sounds to achieve the desired effect according to the needs of the song. The harmony part plays a decorative role in the song, and some of them will permeate the whole work, and some will only be interspersed occasionally.[9]

2.2.2 Hip Hop Beat Generation

Nowadays, most Hip Hop beat is sample-based, which means it uses a piece of melody from another song as a sample. Then producer makes this sample repeat over again to form the musical background of a Hip Hop beat.

Sampling is a digital equivalence of music concrete, wherein common sounds are manipulated to produce musical composition. It also allows musicians to record sound from other instruments or even from nature, and transpose and play them in their music devices.[10]

After got the sampling track, more tracks should be added to the Hip Hop beat to make it has many layers. Meanwhile, adding more layers to the beat can let the beat to generate sounds more in a Hip Hop way regardless which style or genre the sampled melody is.

First thing to add to the beat is MIDI Drum patterns, which will form the drum track of Hip Hop beats. A Hip Hop beat is allowed to have more than one drum loop playing simultaneously, as long as they work together. And compared to other genres of music, Hip Hop has more creative drum tracks. The timing offsets and patterns can be quite distinctive and drums are allowed to go places sonically that other genres will not.[11]

The other important thing to add is baseline. Baseline is usually not so complex in typical Hip Hop beat, but it usually has rather thick and low element, which can make the whole beat more rhythmic. Compared to other genre of music which has baseline, for example rock music, baseline in Hip Hop music is not as intensive as rock music. And baseline in Hip Hop music is usually simple and repeatable.[11]

Other things required is supporting orchestration. In this part, musician should select instruments which work good together and let them plays their part of

sound track. [11] It is like using a band to accompany for your Hip Hop beat. In most sample-based Hip Hop beat, the melody which instrument in this part plays, fits the sample. And nowadays, most Hip Hop beats will use instruments in Synth FX or Synth Pad family just like Electronica.

Last things are Dubs and Snips. These Add-on's are usually some sound effects or extra percussion notes. By adding these into the Hip Hop beat, musicians can make the beat more lively and interesting.

Figure 2.1: Hip Hop Beat Generation[11]

2.2.3 Song Structure

Hip Hop music has fairly easy structure compared with other genre, such as classical music and jazz music. Since Hip Hop beat is used to accompany rapper's content, the structure of Hip Hop beat is usually quite straightforward.

Here are some examples of typical Hip Hop beat structure[12]:

1. Intro / Verse / Hook / Verse / Hook / Verse / Hook x2/ Outro

1. Intro / Hook / Verse / Hook / Verse / Hook / Bridge /Hook x2/ Outro

1. Intro / Verse / Outro

We can see from the above examples that a Hip Hop beat contains only three or four blocks in a song. Each block has their own characters, length and effect, but different blocks might have melodies in common in some occasion.

Intro is starting melody of the whole Hip Hop beat. In this part, rappers usually keep silent or just sing some single words. Thus in intro part, the layers of Hip Hop beat should not be too much to make sure the emotion of whole song will not come directly at the beginning. The length of intro is usually 4-8 bars.[12]

Verse is the part where rappers start to rap. In this part, Hip Hop beat should have strong rhythm to accompany rap. And usually more layers are added in this part. The length of verse is usually eight bars, but sometimes can be sixteen or twelve bars.[12]

Hook is the most attractive part in the whole beat. Just like chorus in a pop song, hook in Hip Hop song has the strongest melody and usually has more layers than any other parts in Hip Hop beat. The length of hook is usually four or eight bars, but sometimes can be sixteen or twelve bars.[12]

Bridge and outro part are common in many Hip Hop beats, but they are not as important as intro, verse and hook. Bridge usually locate between two hooks to make the beat more well-organized and dramatic. It is usually some spoken words or an instrumental solo. The length of bridge is usually four or eight bars.[12] Outro is the ending part of the Hip Hop beat. It is usually composed of some simple melodies and drums, which is similar to the intro part. The length of outro is not so long as other parts, in some Hip Hop beats, outro only takes two bars.

Most Hip Hop beats are generated according to common Hip Hop song structure, but there is no fixed rule of structure of Hip Hop beat. For some old school rappers, e.g. Jay Z, Eminem, Hip Hop beat which they use usually have more than two verses and hooks, the total length of the beat might be up to four or five minutes. In comparison, for trap music rappers, e.g. Higher Brothers, XXXTentacion, the whole song might only contain one verse and no more than two hooks, the total length of trap beat is therefore way shorter than old school Hip Hop beat.

The point is, there is no restriction on the structure of Hip Hop beat. But it will be easier if we generate a Hip Hop beat according to one of the common structures.

2.2.4 Hip Hop Drum Patterns

Drum beat is an important part of Hip Hop music, a good drum beat makes the Hip Hop beat sounds rhythmic and attractive. Different from drum patterns in jazz music and rock music, drum pattern in Hip Hop music is more diverse. And each drum elements in Hip Hop drumming both a singular and group function.[13] In other word, there is usually the occasion that several drum elements play simultaneously.

Most Hip Hop drumming is generated by drum set, either real one or electronic one. Each drum set consists of three elements, bell (hit-hat), high drum (snare) and low drum (bass drum or kick drum). The low drum is responsible for the tempo, it usually match the baseline notes. High drum usually drum in the second and fourth beat in a bar.

Drum Pattern is different in different Hip Hop style. For example, in funky Hip Hop, bell element might play unchanging intensive notes while low drum element has slight deviations.[13] In trap Hip Hop, low drum element will not always play on beat, instead low drum note are quite randomly arranged. Bell element often play triplet notes instead of quarter notes. And since most drum beat of trap Hip Hop is generated electronically, mutations like mute in are always added in drum beat to make it more interesting.

Figure 2.2: Example of Funky Drumming[13]
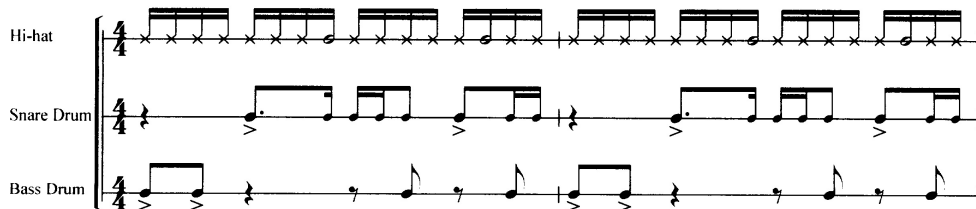
In current Hip Hop music industry, it is quite common for Hip Hop beat producer to use sample to generate Hip Hop drumming. In other words, we can using existing drum patterns in our Hip Hop beat.

2.3 Chord Accompaniment

For support orchestration, there should be some track dealing with the accompaniment of sample melody. And the best method to generate accompaniment

is using chord. There are several rules of arranging chord to the note and chord progression.

2.3.1 Chord

A chord is any harmonic set of pitches consisting of two or more (usually three or more) notes (also called "pitches") that are heard as if sounding simultaneously.[14] When generate chord accompaniment to the melody, we usually consider the on beat note in the bar. Generally, chords which has the note with same pitch as on beat note in the melody can fit that several beats of melody. [15] Also, in a scale, chords may have different quality, some are major, some are minor, and seventh chord is also commonly used in accompaniment.
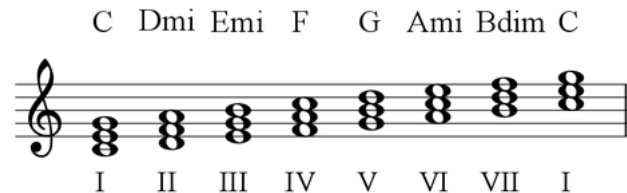

Figure 2.3: Chord in C major

2.3.2 Chord Progression

Chord progression means the successively connecting of the chords, it is also the foundation of harmony and sets the rules for chord changes.

After chosen right chord for the melody, we have to refer to the rules of chord progression to modify the chords we chose. Chords can be divided in three categories: Tonic, Sub-Dominant and Dominant. In a chord scale, 1st, 3rd and 6th chord belong to "Tonic" category, they are usually the starting and ending chord in a chord progression. 5th and 7th chord belong to "Dominant" category. These chords may bring a sense of uncomfortable and panic, they are usually used in the second last position of a chord progression. Dominant Chord can follow other two categories of chord, but will always return to Tonic chords. 2nd and 4th chord belong to "Sub-Dominant" category. Sub-Dominant chords are not suggested to follow Dominant chords. However, they are usually followed by Dominant chords.[16]
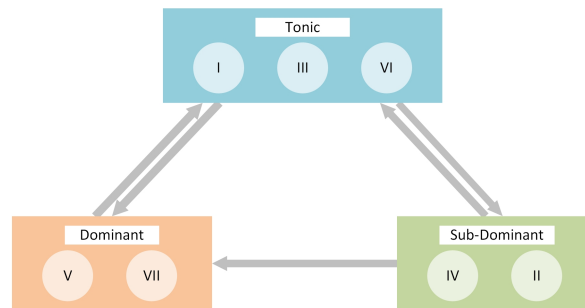
Figure 2.4: Chord Category

What is worthing mentioning, is that some small piece of chord progression, whose chords are in the same category, can also be considered as a chord in a chord category. For example, in C major key, progression: C to Am can be regarded as a tonic chord.

Implementation

3.1 Programming Language and Libraries

This project uses Python as programming language and uses PrettyMIDI and Mido as library extensions.

3.1.1 Python

Python[17] is selected as the programming language of the framework since it is simple to use and can be used to program for generating MIDI items.

3.1.2 PrettyMIDI

PrettyMIDI[18] contains utility function for handling MIDI data, so that it's in a format from which it is easy to modify and extract information. The main functions of PrettyMIDI are assigning instrument to the track, writing notes, adding time signature and key signature information and combining these together to generate a midi melody.

Compared with the previous library extension to generate midi file, namely MIDIUtil, PrettyMIDI has a different way of adding note, but variables required is quite similar, thus it is possible to change the library extension without making huge modification to the framework.

- PrettyMIDI: pretty_midi.Note(velocity, pitch, start, end)

- MIDIUtil: addNote(track; channel; pitch; start; duration; volume)

Another advantage of PrettyMIDI is that it works properly with General MIDI. By using PrettyMIDI, every track can play the instrument sound exactly as the instrument assigned. Also channel 10 for percussion can work properly with PrettyMIDI. In Hip Hop music generation, the choice of instrument is an important aspect and every instrument should sound properly, thus PrettyMIDI is a perfect library extension for Hip Hop music.

3.1.3   Mido

Mido[19] is a library extension which allows user to work with the messages and ports which contains in a midi file.

When dealing with input melody, Mido is a useful tool to get information from Message[20] and Meta Message[21] of the input midi file. For example, we can use functions in Mido to get the notes and key and time signature of input melody. This can help analyzing and manipulating the input melody in the following process.

3.2   Introduction of Framework

3.2.1   Structure

The structure of Robot Composer Framework[3] is designed based on the music theory. The core of the framework in several classes which is fundamental of classical music theory: Note, Chord. Scale, Meter, Key. These classes can be initialized by several variables, and they are used for defining the musical character of the midi file. Meanwhile, with these classes, the whole piece of music is easier to manipulate.

Apart from classes to define the musical character of the music piece, there are also classes to structure the whole music piece hierarchically. Melody defines a piece of melody, which can be initialized by musical character which are defined in other classes. Then a Block defines a part of music, namely intro, verse, chorus and outro. Each block contains several melodies, and a piece of melody will have different variation in different blocks. Piece refers to the whole piece of music, it has subparts like Block and Melody. With the framework, the music is first generated, then added some variations. More precisely, functions to generate melody are first called, then functions to manipulate melody are called. Since the framework is aimed to generate Electronica music, it has many variations which can make the result sound more in a Electronica way. Since Hip Hop

beat also uses some Electronica way of generating music, we can also use some variations in this framework when generate Hip Hop music.

3.2.2   Program Flow

Firstly, the program will read the *m_config.ini* file and gets all parameters of music. Then, these parameters are used to generate a piece of melody, which is a chord progression. This chord progression can be chosen to use predefined chord progression or use parameters to generate. This chord progression is then saved in *Piece* object as the main melody. Afterwards, melody in each track is generate using the main melody according some rules defined in the program. Then, generated track with melody are operated to fit in each blocks. During this process, some mutations are done to the melody in each block in order to make the melody fit the character of the block. After all these process, the final melody is generated. It is also written in .mid form so that it can be played on any devices. The program flow chart of the framework is shown below.
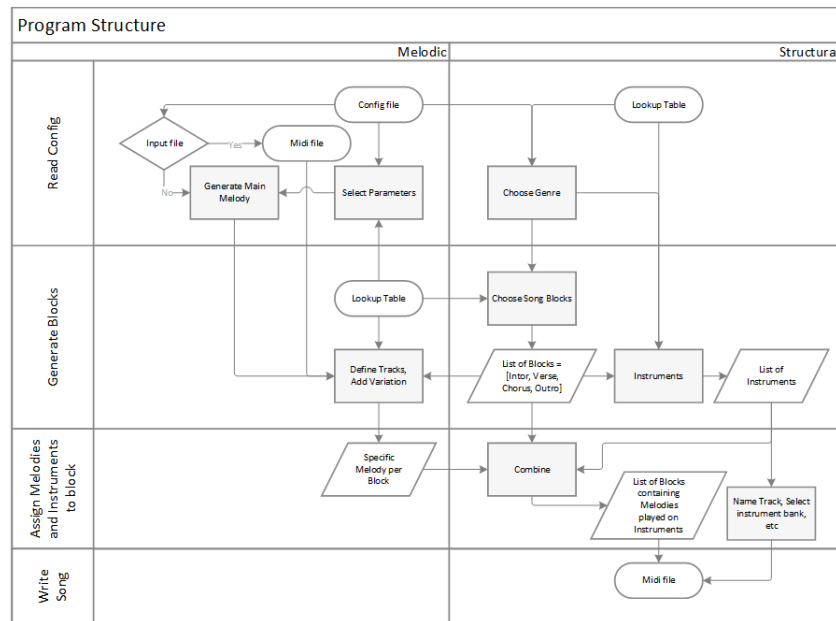

Figure 3.1: Program Flow of Framework[3]

3.2.3   Result

With this Robot Composer Framework, a piece of Electronica music can be generated. It has several blocks, and the position of each blocks can be random.

It has five tracks, namely lead, backing, ambient, bass and percussion. The melody in these tracks varies when entered a different block. Percussion track can be assigned with drum kit, different drum kit can play different sound with the same percussion key note. However, others tracks are failed to assign the instrument. No matter what instruments were set to them, they will all play the sound of Grand Piano.

Regardless of the instrument problem, the melody generated sounds pretty well. The bass melody and ambient melody works well with the chord progression, and the drum beats can have interesting variation in different blocks.

3.3 Hip Hop Robot

With the existing framework, it is possible to generate Hip Hop music. Several problems should be solved and several modifications should be made, in order to generate Hip Hop music with this Framework.

3.3.1 Instrument Problem

A Hip Hop beat should contain tracks playing by different instruments. The current framework does not allow to choose instrument, thus the instrument problem has to be fixed in order to generate Hip Hop beat.

As mentioned in Section 3.1.2, PrettyMIDI[18] is a useful library extension for generating midi files. It works with General MIDI standard, which means by changing MIDIUtil to PrettyMIDI, we can choose instruments from General MIDI Sound Set (See Appendix) and assign them to different tracks. The framework includes the process of assigning instruments to track and finally store the information in *Block* object. What has to be done is to change every sentence in initialization and adding note part which use MIDIUtil into using PrettyMIDI.

After this change, we can use the framework to generate melody with different instruments. However, by using PrettyMIDI, drum kits can not be used any more. In order to generate percussion track, a random instrument is assigned to Channel 10. With the drum note written in its drum melody, it can play percussion. Meanwhile, some customized instrument groups are added in *lookup.py*. Some instruments are assigned to Hip Hop music, users can choose the instrument more efficiently by referring to instrument groups.

3.3.2   Sampled Melody

In this project, sampled melody can be parsed and analyzed by using Mido[19] library extension. To keep the Hip Hop beat sounds harmony, all tracks should have the same time signature, tempo and key. It is an idea to use sampled melody's musical character in generating the beat. Thus, it is important to find sampled Melody's time signature, tempo and key.

These information are all contained in messages and meta messages of sampled melody. By using Mido, *io.read_midi()* function is created to parse the input melody. Using the input melody (midi file) as input, the output consists of tempo, melody and key. Tempo and key is the information which contains in the midi file, and by recording every note's time, duration and pitch, we can get the notes of sampled melody, which can be directly used to generate melody in the framework.

3.3.3   Chord Accompaniment

After got the sampled melody, we can make a chord accompaniment to it. Since the framework use a chord progression as main melody, and many generator functions to generate different blocks and tracks use chord progression as input, generating a chord progression is the easiest way to generate supporting orchestration to the sampled melody.

By using the rules introduced in Section 2.3.1 and 2.3.1, we can get the chord progression to sampled melody. After parsing it and getting the information of every notes in sampled melody, we can choose the on beat note by checking the note time. Then according to the note's pitch and key of sampled melody, we can get the chords related to each on beat note. Then we use the rule of chord progression to check the current chord progression, if necessary and possible, some chords should be changed into other chords. After checking each chords and making modifications, we can use this chord progression as main melody and use it to generate other tracks of melodies.

3.3.4   Drumming

In terms of drumming, the idea is two methods are offered in this Robot Composer. One is to generate a drum beat using Electronica way, which is keep using the drum generation function in this framework. Another is to generate a drum beat using Hip Hop way. Since nowadays many sampled-base Hip Hop music uses sampled drum beat directly in the beat, we can add some common Hip Hop

drum beat in this program to let user choose from. If user wants to generate drum beat in Hip Hop way, he or she can insert the drum beat type in *drum_type* , then the drum notes of the drum beat chosen can be directly used and written in tracks and blocks.

3.3.5   Hip Hop Beat Structure

Since the Hip Hop beat generated in this program is sampled-based, the song structure should be related to the length of sampled melody. In this program, we choose sampled melody with length of eight bars. Thus the length of each blocks should be multiples of eight to make the whole beat sounds harmony.

The total length of the Hip Hop beat is first to be defined. Then by assigning percentage and sequence of each blocks, we can assign the length of each block. In this way, the length of each blocks is guaranteed to be the multiples of length of sampled melody. And the Hip Hop beat structure can be modified by changing percentage and sequence of each blocks.

3.3.6   Program Flow

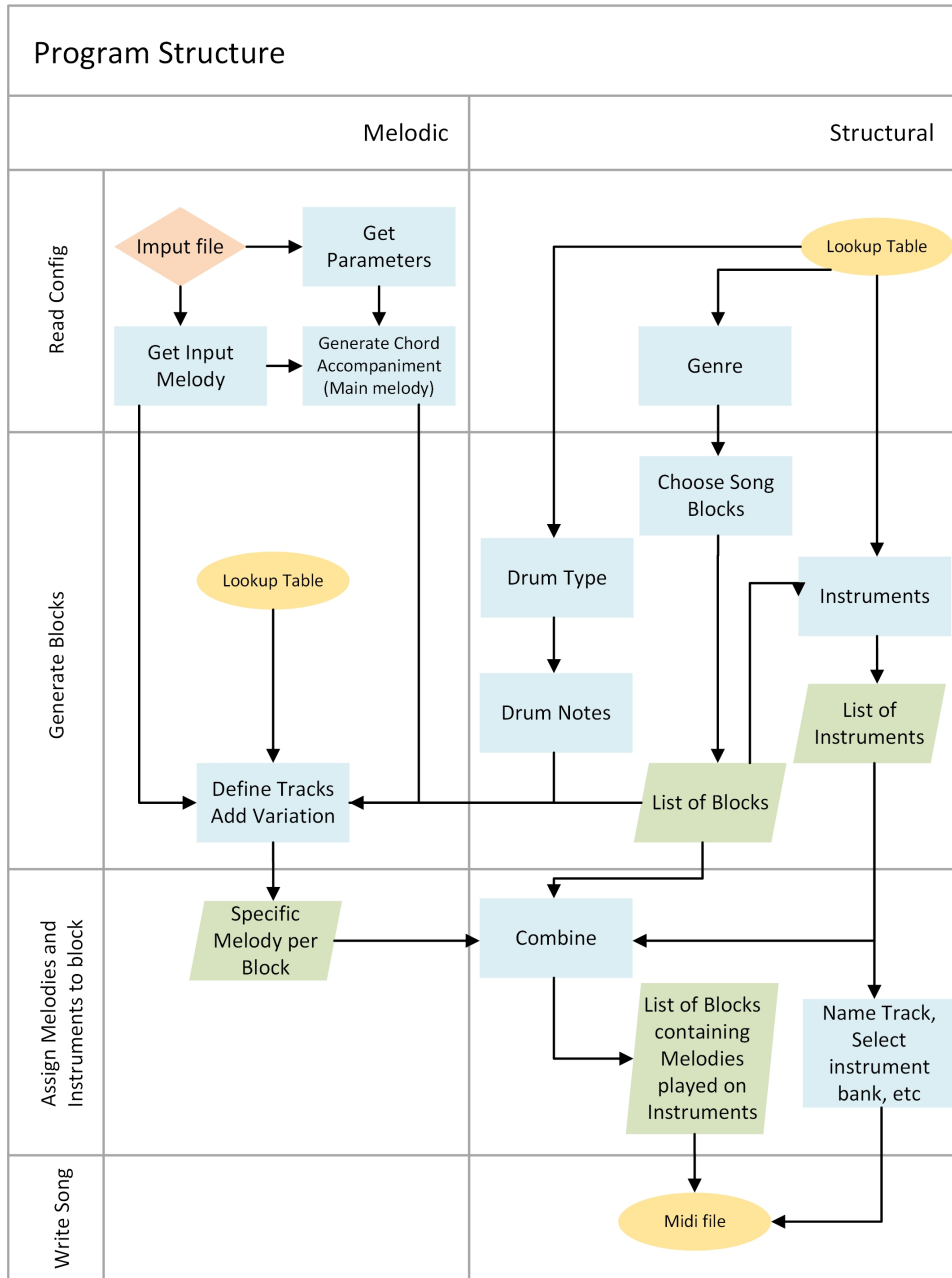The Program Flow after modification is shown below.

Figure 3.2: Program Flow

Result

Using this Hip Hop Robot Composer, it is possible to generate a midi file whose genre is Hip Hop. There are five tracks in one midi file. Lead track plays accompaniment to sampled melody in verse and hook blocks. Backing track plays varieties of chords in hook part to emphasize the rhythmic character of Hip Hop music. Input track plays sampled melody and makes it a loop. Bass track plays bass note, and Percussion track plays drum beat either generated by robot composer or used fixed drum pattern.

Hip Hop is quite a freestyle music genre, it has few musical rules in it. Thus it is hard to judge whether the music generated is a typical Hip Hop beat or not. But at least by using Hip Hop instruments and using Hip Hop drum patterns, we can make the Hip Hop beat generated more rhythmic and attractive, which are definitely characters of Hip Hop music.

Discussion

Using this Hip Hop Robot Composer a music with many layers can be generated. In my opinion, the main work of this project is not generating Hip Hop beat by using programming, but to understand the framework and make the best modification to it to make it more powerful and diverse.

5.1 Personal Insight

During the process of doing project, there are actually many decisions I made wasted my time. While dealing with instrument problem, I insist on checking the problem of the code at first, only after a friend of mine told me about another midi library extension, I made up my mind to give up the current library extension and start using another one.

It is also a pity that I did not realize most of my supervisor's wonderful ideas. For example, I once had problem in finding the key of input melody. My supervisor suggested me to find the key of music in a statistical way. However, probably because I did not use this method properly, I cannot get right result by using this method. I do think this method makes sense and can deal with input melody which do not contains key information, but I have to give up it.

Although there is almost no Hip Hop music theory, and the beat generated might be regarded as Electronica music, I am still convinced that the Hip Hop beat generated can be used in Hip Hop performance.

5.2 Future Work

With this framework with great extendability, more works could be done to increase this robot composer's functions.

In terms of Hip Hop, we can add a track which offers rapper suggestions for arranging lyrics. This is the work I did not finish. In order to do this work, more background knowledge of Hip Hop is required. Meanwhile, Hip Hop has many styles and some of them are rather different from each other. Further Modification can be made to generate different styles of Hip Hop beat.

In terms of the use of this Robot Composer, I think a function to convert one genre to another genre can be added in it. Although theoretically, it can already generate Hip Hop beat with folk music or other genre of music as input melody.

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Appendix Chapter

General MIDI instrument list

1-8 Piano	33-40 Bass	65-72 Reed	97-104 Synth FX
01. Acoustic Grand Piano	33. Acoustic Bass	65. Soprano Sax	97. SFX 1 (rain)
02. Bright Acoustic Piano	34. Electric Bass (finger)	66. Alto Sax	98. SFX 2 (soundtrack)
03. Electric Grand Piano	35. Electric Bass (pick)	67. Tenor Sax	99. SFX 3 (crystal)
04. Honky-tonk Piano	36. Fretless Bass	68. Baritone Sax	100. SFX 4 (atmosphere)
05. Electric Piano 1	37. Slap Bass 1	69. Oboe	101. SFX 5 (brightness)
06. Electric Piano 2	38. Slap Bass 2	70. English Horn	102. SFX 6 (goblins)
07. Harpsichord	39. Synth Bass 1	71. Bassoon	103. SFX 7 (echoes)
08. Clavi	40. Synth Bass 2	72. Clarinet	104. SFX 8 (sci-fi)

9-16 Chromatic Percussion	41-48 Strings	73-80 Pipe	105-112 Ethnic
09. Celesta	41. Violin	73. Piccolo	105. Sitar
10. Glockenspiel	42. Viola	74. Flute	106. Banjo
11. Music Box	43. Cello	75. Recorder	107. Shamisen
12. Vibraphone	44. Contrabass	76. Pan Flute	108. Koto
13. Marimba	45. Tremolo Strings	77. Blown Bottle	109. Kalimba
14. Xylophone	46. Pizzicato Strings	78. Shakuhachi	110. Bag pipe
15. Tubular Bells	47. Orchestral Harp	79. Whistle	111. Fiddle
16. Dulcimer	48. Timpani	80. Ocarina	112. Shanai

17-24 Organ	49-56 Ensemble	81-88 Synth Lead	113-120 Percussion
17. Drawbar Organ	49. String Ensemble 1	81. Synth Lead 1 (square)	113. Tinkle Bell
18. Percussive Organ	50. String Ensemble 2	82. Synth Lead 2 (sawtooth)	114. Agogo
19. Rock Organ	51. SynthStrings 1	83. Synth Lead 3 (calliope)	115. Steel Drums
20. Church Organ	52. SynthStrings 2	84. Synth Lead 4 (chiff)	116. Woodblock
21. Reed Organ	53. Choir Aahs	85. Synth Lead 5 (charang)	117. Taiko Drum
22. Accordion	54. Voice Oohs	86. Synth Lead 6 (voice)	118. Melodic Tom
23. Harmonica	55. Synth Voice	87. Synth Lead 7 (fifths)	119. Synth Drum
24. Bandoneon	56. Orchestra Hit	88. Synth Lead 8 (bass + lead)	120. Reverse Cymbal

25-32 Guitar	57-67 Brass	89-96 Synth Pad	121-128 Sound FX
25. Acoustic Guitar (nylon)	57. Trumpet	89. Synth Pad 1 (new age)	121. Guitar Fret Noise
26. Acoustic Guitar (steel)	58. Trombone	90. Synth Pad 2 (warm)	122. Breath Noise
27. Electric Guitar (jazz)	59. Tuba	91. Synth Pad 3 (polysynth)	123. Seashore
28. Electric Guitar (clean)	60. Muted Trumpet	92. Synth Pad 4 (choir)	124. Bird Tweet
29. Electric Guitar (muted)	61. French Horn	93. Synth Pad 5 (bowed)	125. Telephone Ring
30. Overdrive Guitar	62. Brass Section	94. Synth Pad 6 (metallic)	126. Helicopter
31. Distortion Guitar	63. SynthBrass 1	95. Synth Pad 7 (halo)	127. Applause
32. Guitar harmonics	64. SynthBrass 2	96. Synth Pad 8 (sweep)	128. Gunshot

Figure A.1: GM1 Instrument