HOLLABACH

Final Report

COMS W4115: Programming Languages and Translators

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# 1. Introduction

HOLLABACH is a language for composing MIDI based music. With HOLLABACH, composers can create compositions similar to writing programming code and utilize common programming tools and resources with their compositions. The language also includes support for loops, conditional statements and variables for the often repetitive or algorithmic nature of musical compositions. HOLLABACH is designed to help composers create music efficiently, compose music collaboratively and abstract away the semantics of the MIDI specification.

## 1.1. MIDI

MIDI is a protocol and digital interface for digital music recording and playback. It was published in 1983 and has been the most popular protocol for composing and playing electronic music. MIDI is widely supported by most digital instrument creators and most modern computers have built in software to play back recorded MIDI music. HOLLABACH produces MIDI files as final compiled output.

# 2. Language Tutorial

A HOLLABACH composition is a group of instruments with a sequence of musical statements for each instrument. These statements can be musical measures, loop structures, conditional statements, variables or time signature declarations.

## 2.1. Hello World!

inst Piano {

[C3/1]

}

This example program creates a composition that contains one instrument, a Piano, and has that instrument play a C note for four beats (one measure). The inst construct declares the instrument and the body of the construct is the musical sequence to be played by the instrument.

In this case we have one measure in the sequence, declared by the brackets, with one note in the measure. The note is a C note, as specified by the starting letter. The following digit specifies the octave and the trailing digit specifies the inverse of the length. A value of one means 1 measure/ 1 = 1 measure. If the value had been a 4, the length would be 1 measure / 4 = ¼ measure, or a quarter note. Valid note lengths are discussed in more detain the section 3.2.2.

To make this more interesting, we can add more notes and measures to our original example:

inst Piano {

[C3/1]

[C3/4+G3/4 R C/3/4+G3/4 A3/4]

}

In this composition, we have the original measure, followed by a more complex measure. During this new measure, we have two quarter note chords, denoted by the + sign between the notes of the chord. We also have a rest note, denoted by the single character ‘R’. The notes in the measure are played left to right and the starting beat in the measure is denoted by

Position / (total note positions in the measure)

In this case, the second measure has four positions, so the second chord(in position 3) would be played on beat 3 of the measure.

## 2.2. Compiling and running

Compiling a HOLLABACH program uses the executable hollabach. Hollabach generates the .holla bytecode by running:

$ ./hollabach –c mycomp.holla < mycomp.bach

From here, the bytecode can be translated into a MIDI file by running

$ cd CSV2JAVA; java ../mycomp.holla ../mycomp.midi; cd ..

From here, the composition can be played using any MIDI compatible playback device or program.

## 2.3. More Examples

In this example, we create a simple composition of the folk song, Hot Cross Buns:

inst Piano {

loop 2 {

hcb = [C3/4 B3/4 A3/4 R]

}

[A3/4 A3/4 B3/4 B3/4]

hcb

}

We see two new language features here, the loop and the variable. The loop allows us to repeat a section of code a set amount of times before continuing. In this case we repeat the enclosing measure twice. The enclosing measure is also declared bound to the variable hcb. We can then use hcb in the last line of the composition to insert that measure without having to retype it.

# 3. Language Manual

# 3.1. Lexical Conventions

## 3.1.1 Comments

A comment is preceded by ‘/\*’ and ended with '\*/‘. These comments may span several lines but cannot be embedded in another comment.

## 3.1.2 Identifiers

Identifiers are a sequence of letters, digits, and underscores. Identifiers cannot begin with a digit and cannot be a reserved keyword.

*Identifier -> letter(letter | digit | underscore)*

## 3.1.3 Reserved Keywords

The group of keywords that exist for defining language related function functionality are:

*loop, timesig, inst, if, else*

These keywords cannot be used for identifiers.

## 3.1.4 Whitespace

A whitespace character is used to separate tokens and is otherwise ignored. Whitespace characters include the space, tab and newline characters.

# 3.2. Basic types/constants:

## 3.2.1 Integers:

Integer Constants are a sequence of digits separated by whitespace. Some uses for integers include representing Time Signature declarations, If statement conditionals and loop iteration counts.

*Constant -> digit+*

## 3.2.2 Note

A Note is a single contiguous musical sound. An example note is:

A#3/4

This defines a note of pitch A# in octave 3 with a length of a quarter note (1/4). The backslash denotes the beginning of the declaration of note length. Length is determined by the denominator of the fraction of a measure it lasts, such as 4 for quarter note, 2 for half note, 8 for eigth note. A sixteenth note is specified with just ‘6’ to make note length consistent. Valid lengths include:

1 - whole note

2 - half note

4 - quarter note

8 - eighth note

6 - sixteenth note.

The available pitches include A-G and an additional # or b character to represent sharp or flat notes. The octave section can contain a single digit between 0 and 6. A rest note is declared with just the letter R.The overall lexical pattern for identifying a note is

*Note -> [‘A’-‘G’, ‘R’][‘#’|’b’]?[‘0’-‘6’][’/’][‘1’|’2’|’4’|’8’|’6’]*

# 3.3. Complex types and Expressions

## 3.3.1 Chord

A chord is one or more notes that will be played simultaneously. An example chord:

C2/4+G3/4+A3/4+C3/4

This defines a chord of four notes that lasts for a quarter beat. Notes in the chord may end at different time. The goal is that all of the notes in a chord start at the same time.

*chord -> note | note + chord*

## 3.3.2 Measure

A Measure is a musical unit in a composition. It contains an array of chords and Rests. The position in the array indicates when the chord is played based on the length of the array. The array can be up to 32 units in length and it subdivides the measure into as many note start positions as there are entries. Valid lengths are 0, 1, 2, 3, 4, 8, 16, 32. For example,

[A2/8 A2/8 A2/8 A2/8]

will play an eighth note every quarter beat for the measure. The array is declared using an open bracket (‘[‘) and finished using a closed bracket (‘]’) and split using whitespace.

*Measure -> chord \**

## 3.3.2.1 Declaring a Measure as a Variable

Measures may also optionally be declared with an identifier for reuse in later lines in a composition. For example:

aEveryFour = [A2/8 A2/8 A2/8 A2/8]

It can then be used in later lines with simply:

aEveryFour

If a measure identifier is redefined the compiler will override the current definition with the new definition, but all previous uses of it will remain unchanged.

## 3.3.3 Rests

A rest can be declared in a measure using the token ‘R’ in place of a note. No notes will be started at that position, although a previous note may sustain through the rest. Whole measure rests can be declared by omitting the body of the measure like so:

[]

## 3.3.4 Instrument

An Instrument creates a musical ‘thread’, a tone and series of notes that will be attributed to one musical instrument in a composition. The optional body contains a list of sequential measures and optional loop, conditional and time signature statements. Multiple Instruments are allowed per file. Each can be thought of as a different musician. Instruments are declared using the ‘inst’ tag.

inst Piano{

     timesig =4

     [G2/8 A2/8 B2/8 C2/8 D2/8 E2/8 F2/8 G3/8]

     loop 2 {

          [G2/4+C2/4+G3/4 R G2/4+C2/4+G3/4 R]

     }

}

The Instrument tone is declared after the inst tag and the Instrument definition appears between the ‘{‘ and ‘}’ characters. Each measure, time signature change or loop is separated by a newline character and proceed sequentially.

*Instrument -> ‘inst’ string\_lit ‘{‘ stmt \* ‘}’*

## 3.3.5 Time Signature

Time Signature is an attribute that determines how many beats occur in a measure. Dividing this value by the beats per minute gives you the absolute time length of a single measure. Time Signature is declared with the tag ‘timesig=’ and defined with a positive integer that follows.  An example declaration is:

     timesig=4

After declaring a Time Signature value, all measures that follow it until another time signature is declared will inherit this value. If no value is declared in the instrument, the value is assumed to be 4.

## 3.3.6 Loops

A loop statement allows a measure or set of measures to be repeated a given amount of times. A loop is declared with the keyword ‘loop’ and followed by an integer representing the number of repetitions. Following the integer, the loop contents are declared with a leading ‘{‘ and a trailing ‘}’. For example:

loop 2 {

          [G2/4+C2/4+G3/4 R G2/4+C2/4+G3/4 R]

}

A loop contents can include any combination of measures, if statements, variables or embedded loops.

*Loop -> ‘loop’ literal ‘{‘ stmt \* ‘}’*

## 3.3.7 Conditional Statements

A composer can use an conditional statement to change the behavior of certain loop iterations in a loop. The composer declares the conditional using an If statement, followed by the loop iteration number that the If statement should trigger. The iteration starts at 0 and increments until it is equal to the specified number. This means an if statement meant to trigger on the first iteration should use 0 as it’s conditional. The composer can also use an else statement after an If to trigger on the negation case of the If statement. The If body is declared after the conditional between brackets. The body can contain measures or additional loops.

If -> ‘if’ literal ‘{‘ stmt\* ‘}’ ‘else’ ‘{‘ stmt\* ‘}’ | ‘if’ literal ‘{‘ stmt\* ‘}’

## 3.3.8 Composition

A composition a single ’program’ in HOLLABACH. It is essentially a list of Instrument declarations and their definitions. The order of Instruments does not matter outside of the track ordering in the final MIDI output.

*Comp -> inst \**

# 3.4. Variable Scope

## 3.4.1 Measure Identifier

The scope of a measure identifier in HOLLABACH is global to the composition once it is defined. Any references before it is defined in the composition will cause compiler errors. If the same identifier is declared twice in a composition, the second value will override the original value for all uses after the second declaration.

## 3.4.2 Loop

A loop has an implicit variable, the loop iteration number. The scope of this variable is inside the loop (between the brackets) and is exclusively used in if statements. An if statement conditional always refers to the lowest loop. For example, if we have loop B embedded in loop A and an if statement in loop B, the conditional will refer to the iteration number of loop B. If an If statement is declared not inside a loop, it will only trigger if the conditional is 0, as the loop iteration number not inside a loop is always 0.

# 4. Project Plan

## 4.1. Project Timeline

The following time periods were set for major development objectives:

|  |  |
| --- | --- |
| Date | Task |
| 6/2- 6/11 | Language Proposal |
| 6/12- 7/2 | Language Design and Reference Manual |
| 7/3 - 8/8 | Environment set up and development of End to End execution, completed Scanner and Parser |
| 8/9 – 8/22 | Feature expansion, Testing Framework development, composing Final Report |

## 4.2. Programming Style Guide

Effort was made to document as much of the code as possible and try to adhere to the programming style guide created by the maintainers of Ocaml at:

<http://caml.inria.fr/resources/doc/guides/guidelines.en.html>

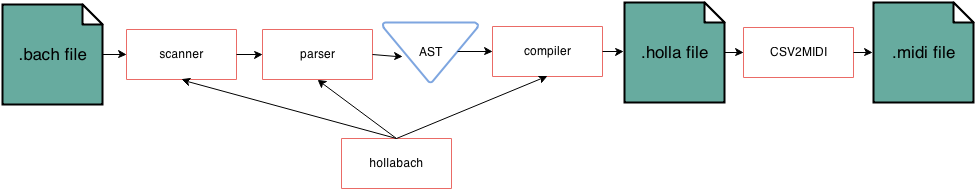
## 4.3. Development Environment

The project was developed on OSX using Git and Github for version control and Make for building. The compiler was built in Ocaml and the translator/interpreter was built in Java. Ocamllex was used **for lexing and** ocamlyacc was used to create the grammar for the language. Shell scripting was used for executing automated tests.

## 4.4. Project Log

|  |  |
| --- | --- |
| Date | Progress |
| 6/2? | Project Start |
| 6/11 | Language Proposal finished |
| 6/24 | 1st draft of Language Grammar |
| 7/2 | Language Reference Manual submitted |
| 7/14 | Revised Language Grammar based on feedback |
| 7/18 | Development Environment and Code Repository set up |
| 8/11 | End to End execution and first test programs created |
| 8/12 | MIDI output |
| 8/19 | Automated Test Suite working |
| 8/something | **Added features and stuff** |
| 8/22 | Submitted final code and Report |

# 5. Architectural Design



HOLLABACH follows a similar pattern to most compilers, using lexical analysis, a parser and a compiler to translate source code into bytecode. The system takes input of a .bach file of HOLLABACH source code and the scanner uses Ocamllex, a version of lex for Ocaml, to generate tokens. The parser then converts these tokens into an Abstract Syntax tree by rules defined using Ocamlyacc, a version of yacc for Ocaml. This AST is used as input to the compiler, which converts the data into bytecode that is easy for the interpreter to handle and then writes this data out to a .holla file. The holla file is essentially a CSV file consisting of track and note information. This file is then passed into the interpreter, CSV2MIDI, which generates a MIDI file from the data.

## 5.1. Individual Contributions

|  |  |
| --- | --- |
| Component | Contributors |
| Scanner | Craig Darmetko, Stephen Edwards |
| Parser | Craig Darmetko, Stephen Edwards |
| Compiler | Craig Darmetko |
| Interpreter (CSV2MIDI) | Craig Darmetko, Stephen Steffes |
| Testing | Craig Darmetko, Stephen Edwards |

## 5.2 CSV2MIDI

The Interpreter and bytecode representation for HOLLABACH is largely based on CSV2MIDI, a java program written by Stephen Steffes to translate data in a CSV file to a MIDI file. HOLLABACH extended the original functionality to support some of the unique features in the HOLLABACH language.

# 6. Test Plan

## 6.1. Test Framework

Although not exhaustive, the test plan for HOLLABACH is meant to exercise important features in a simple and repeatable manner. HOLLABACH uses a series of test programs, detailed in Section 6.3, and a shell script that compiles the program and compares it against ground truth to report any discrepancies. Each test program exercises a certain feature or the composition of features. Having multiple separate test programs isolates errors and speeds up resolution of bugs. Tests can be run by executing the program testall.sh.

## 6.2. Example Program and Output

Below is an example program that plays the first verse of the song Chopstix with two instruments, a Piano and an Acoustic Bass.

inst Piano{

timesig=3

loop 2{

loop 2{

[G3/4+F3/4 G3/4+F3/4 G3/4+F3/4]

}

loop 2{

[G3/4+E3/4 G3/4+E3/4 G3/4+E3/4]

}

[B3/4+D3/4 B3/4+D3/4 B3/4+D3/4]

[B3/4+D3/4 A3/4+E3/4 B3/4+D3/4]

[C3/4+C4/4 R C3/4+C4/4]

if 1 {

[C3/2+C4/2 R]

}

else{

[C3/4+C4/4 B3/4+D3/4 A3/4+E3/4]

}

}

}

inst AcousticBass{

timesig=3

loop 2{

loop 2{

beg = [C3/8 G3/4+F3/4 G3/4+F3/4]

}

loop 2{

[C3/8 G3/4+E3/4 G3/4+F3/4]

}

[D3/8 G3/4+F3/4 G3/4+F3/4]

[D3/8 G3/4+E3/4 G3/4+E3/4]

beg

if 1 {

[C3/2 R]

}

else{

beg

}

}

}

This program generates the bytecode output below:

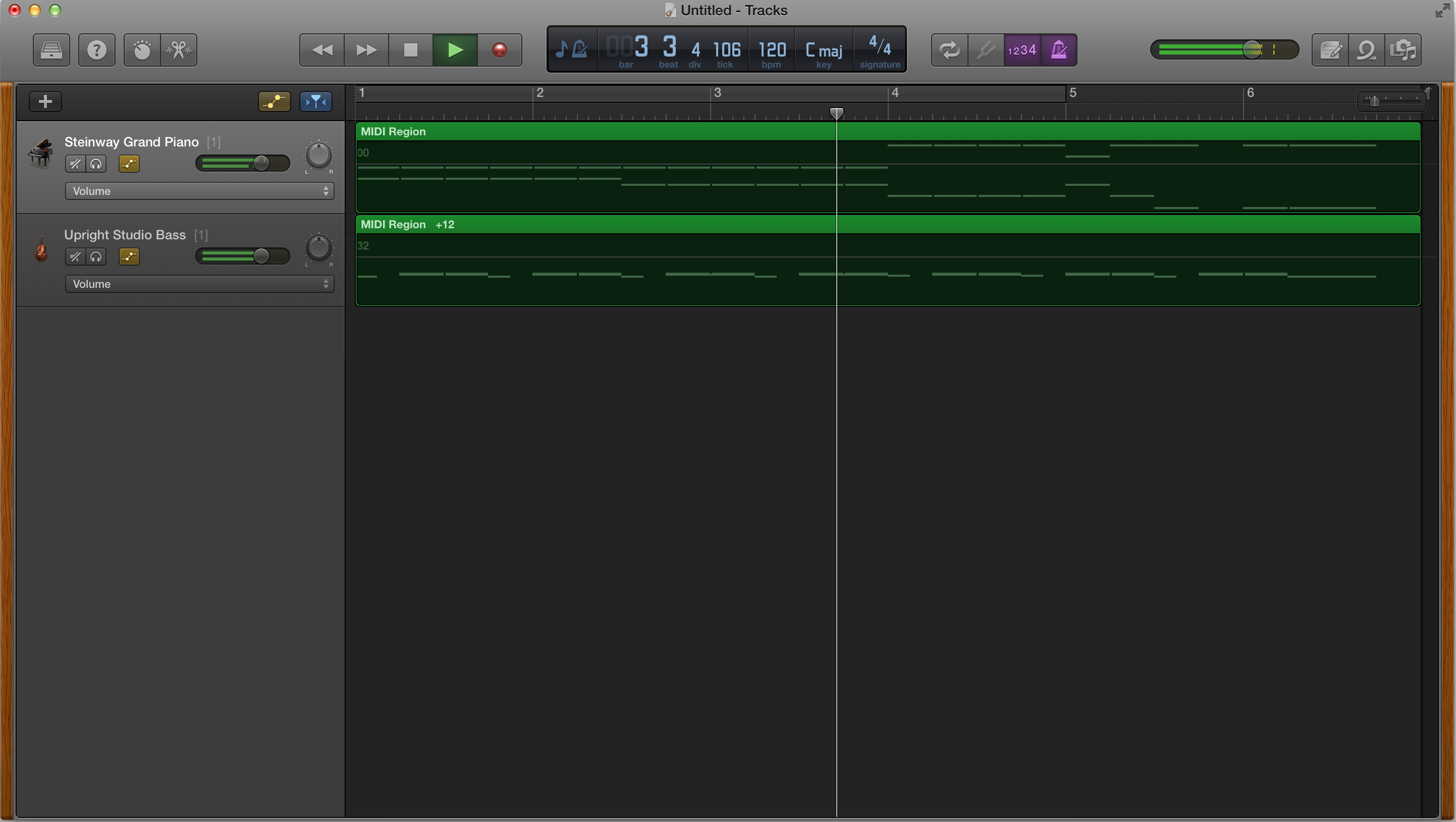
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Timing Resolution (pulses per quarter note) | | | | | | |  |
| 4 |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Instrument | 0 | Piano | Instrument | 32 | AcousticBass | |  |
|  |  |  |  |  |  |  |  |
| Tick | Note | Velocity | Length | Tick | Note | Velocity | Length |
| 0 | 53 | 80 | 4 |  |  |  |  |
| 0 | 55 | 80 | 4 |  |  |  |  |
| 4 | 53 | 80 | 4 |  |  |  |  |
| 4 | 55 | 80 | 4 |  |  |  |  |
| 8 | 53 | 80 | 4 |  |  |  |  |
| 8 | 55 | 80 | 4 |  |  |  |  |
| 12 | 53 | 80 | 4 |  |  |  |  |
| 12 | 55 | 80 | 4 |  |  |  |  |
| 16 | 53 | 80 | 4 |  |  |  |  |
| 16 | 55 | 80 | 4 |  |  |  |  |
| 20 | 53 | 80 | 4 |  |  |  |  |
| 20 | 55 | 80 | 4 |  |  |  |  |
| 24 | 52 | 80 | 4 |  |  |  |  |
| 24 | 55 | 80 | 4 |  |  |  |  |
| 28 | 52 | 80 | 4 |  |  |  |  |
| 28 | 55 | 80 | 4 |  |  |  |  |
| 32 | 52 | 80 | 4 |  |  |  |  |
| 32 | 55 | 80 | 4 |  |  |  |  |
| 36 | 52 | 80 | 4 |  |  |  |  |
| 36 | 55 | 80 | 4 |  |  |  |  |
| 40 | 52 | 80 | 4 |  |  |  |  |
| 40 | 55 | 80 | 4 |  |  |  |  |
| 44 | 52 | 80 | 4 |  |  |  |  |
| 44 | 55 | 80 | 4 |  |  |  |  |
| 48 | 50 | 80 | 4 |  |  |  |  |
| 48 | 59 | 80 | 4 |  |  |  |  |
| 52 | 50 | 80 | 4 |  |  |  |  |
| 52 | 59 | 80 | 4 |  |  |  |  |
| 56 | 50 | 80 | 4 |  |  |  |  |
| 56 | 59 | 80 | 4 |  |  |  |  |
| 60 | 50 | 80 | 4 |  |  |  |  |
| 60 | 59 | 80 | 4 |  |  |  |  |
| 64 | 52 | 80 | 4 |  |  |  |  |
| 64 | 57 | 80 | 4 |  |  |  |  |
| 68 | 50 | 80 | 4 |  |  |  |  |
| 68 | 59 | 80 | 4 |  |  |  |  |
| 72 | 60 | 80 | 4 |  |  |  |  |
| 72 | 48 | 80 | 4 |  |  |  |  |
| 80 | 60 | 80 | 4 |  |  |  |  |
| 80 | 48 | 80 | 4 |  |  |  |  |
| 84 | 60 | 80 | 4 |  |  |  |  |
| 84 | 48 | 80 | 4 |  |  |  |  |
| 88 | 50 | 80 | 4 |  |  |  |  |
| 88 | 59 | 80 | 4 |  |  |  |  |
| 92 | 52 | 80 | 4 |  |  |  |  |
| 92 | 57 | 80 | 4 |  |  |  |  |
| 96 | 53 | 80 | 4 |  |  |  |  |
| 96 | 55 | 80 | 4 |  |  |  |  |
| 100 | 53 | 80 | 4 |  |  |  |  |
| 100 | 55 | 80 | 4 |  |  |  |  |
| 104 | 53 | 80 | 4 |  |  |  |  |
| 104 | 55 | 80 | 4 |  |  |  |  |
| 108 | 53 | 80 | 4 |  |  |  |  |
| 108 | 55 | 80 | 4 |  |  |  |  |
| 112 | 53 | 80 | 4 |  |  |  |  |
| 112 | 55 | 80 | 4 |  |  |  |  |
| 116 | 53 | 80 | 4 |  |  |  |  |
| 116 | 55 | 80 | 4 |  |  |  |  |
| 120 | 52 | 80 | 4 |  |  |  |  |
| 120 | 55 | 80 | 4 |  |  |  |  |
| 124 | 52 | 80 | 4 |  |  |  |  |
| 124 | 55 | 80 | 4 |  |  |  |  |
| 128 | 52 | 80 | 4 |  |  |  |  |
| 128 | 55 | 80 | 4 |  |  |  |  |
| 132 | 52 | 80 | 4 |  |  |  |  |
| 132 | 55 | 80 | 4 |  |  |  |  |
| 136 | 52 | 80 | 4 |  |  |  |  |
| 136 | 55 | 80 | 4 |  |  |  |  |
| 140 | 52 | 80 | 4 |  |  |  |  |
| 140 | 55 | 80 | 4 |  |  |  |  |
| 144 | 50 | 80 | 4 |  |  |  |  |
| 144 | 59 | 80 | 4 |  |  |  |  |
| 148 | 50 | 80 | 4 |  |  |  |  |
| 148 | 59 | 80 | 4 |  |  |  |  |
| 152 | 50 | 80 | 4 |  |  |  |  |
| 152 | 59 | 80 | 4 |  |  |  |  |
| 156 | 50 | 80 | 4 |  |  |  |  |
| 156 | 59 | 80 | 4 |  |  |  |  |
| 160 | 52 | 80 | 4 |  |  |  |  |
| 160 | 57 | 80 | 4 |  |  |  |  |
| 164 | 50 | 80 | 4 |  |  |  |  |
| 164 | 59 | 80 | 4 |  |  |  |  |
| 168 | 60 | 80 | 4 |  |  |  |  |
| 168 | 48 | 80 | 4 |  |  |  |  |
| 176 | 60 | 80 | 4 |  |  |  |  |
| 176 | 48 | 80 | 4 |  |  |  |  |
| 180 | 60 | 80 | 8 |  |  |  |  |
| 180 | 48 | 80 | 8 |  |  |  |  |
|  |  |  |  | 0 | 48 | 80 | 2 |
|  |  |  |  | 4 | 53 | 80 | 4 |
|  |  |  |  | 4 | 55 | 80 | 4 |
|  |  |  |  | 8 | 53 | 80 | 4 |
|  |  |  |  | 8 | 55 | 80 | 4 |
|  |  |  |  | 12 | 48 | 80 | 2 |
|  |  |  |  | 16 | 53 | 80 | 4 |
|  |  |  |  | 16 | 55 | 80 | 4 |
|  |  |  |  | 20 | 53 | 80 | 4 |
|  |  |  |  | 20 | 55 | 80 | 4 |
|  |  |  |  | 24 | 48 | 80 | 2 |
|  |  |  |  | 28 | 52 | 80 | 4 |
|  |  |  |  | 28 | 55 | 80 | 4 |
|  |  |  |  | 32 | 53 | 80 | 4 |
|  |  |  |  | 32 | 55 | 80 | 4 |
|  |  |  |  | 36 | 48 | 80 | 2 |
|  |  |  |  | 40 | 52 | 80 | 4 |
|  |  |  |  | 40 | 55 | 80 | 4 |
|  |  |  |  | 44 | 53 | 80 | 4 |
|  |  |  |  | 44 | 55 | 80 | 4 |
|  |  |  |  | 48 | 50 | 80 | 2 |
|  |  |  |  | 52 | 53 | 80 | 4 |
|  |  |  |  | 52 | 55 | 80 | 4 |
|  |  |  |  | 56 | 53 | 80 | 4 |
|  |  |  |  | 56 | 55 | 80 | 4 |
|  |  |  |  | 60 | 50 | 80 | 2 |
|  |  |  |  | 64 | 52 | 80 | 4 |
|  |  |  |  | 64 | 55 | 80 | 4 |
|  |  |  |  | 68 | 52 | 80 | 4 |
|  |  |  |  | 68 | 55 | 80 | 4 |
|  |  |  |  | 72 | 48 | 80 | 2 |
|  |  |  |  | 76 | 53 | 80 | 4 |
|  |  |  |  | 76 | 55 | 80 | 4 |
|  |  |  |  | 80 | 53 | 80 | 4 |
|  |  |  |  | 80 | 55 | 80 | 4 |
|  |  |  |  | 84 | 48 | 80 | 2 |
|  |  |  |  | 88 | 53 | 80 | 4 |
|  |  |  |  | 88 | 55 | 80 | 4 |
|  |  |  |  | 92 | 53 | 80 | 4 |
|  |  |  |  | 92 | 55 | 80 | 4 |
|  |  |  |  | 96 | 48 | 80 | 2 |
|  |  |  |  | 100 | 53 | 80 | 4 |
|  |  |  |  | 100 | 55 | 80 | 4 |
|  |  |  |  | 104 | 53 | 80 | 4 |
|  |  |  |  | 104 | 55 | 80 | 4 |
|  |  |  |  | 108 | 48 | 80 | 2 |
|  |  |  |  | 112 | 53 | 80 | 4 |
|  |  |  |  | 112 | 55 | 80 | 4 |
|  |  |  |  | 116 | 53 | 80 | 4 |
|  |  |  |  | 116 | 55 | 80 | 4 |
|  |  |  |  | 120 | 48 | 80 | 2 |
|  |  |  |  | 124 | 52 | 80 | 4 |
|  |  |  |  | 124 | 55 | 80 | 4 |
|  |  |  |  | 128 | 53 | 80 | 4 |
|  |  |  |  | 128 | 55 | 80 | 4 |
|  |  |  |  | 132 | 48 | 80 | 2 |
|  |  |  |  | 136 | 52 | 80 | 4 |
|  |  |  |  | 136 | 55 | 80 | 4 |
|  |  |  |  | 140 | 53 | 80 | 4 |
|  |  |  |  | 140 | 55 | 80 | 4 |
|  |  |  |  | 144 | 50 | 80 | 2 |
|  |  |  |  | 148 | 53 | 80 | 4 |
|  |  |  |  | 148 | 55 | 80 | 4 |
|  |  |  |  | 152 | 53 | 80 | 4 |
|  |  |  |  | 152 | 55 | 80 | 4 |
|  |  |  |  | 156 | 50 | 80 | 2 |
|  |  |  |  | 160 | 52 | 80 | 4 |
|  |  |  |  | 160 | 55 | 80 | 4 |
|  |  |  |  | 164 | 52 | 80 | 4 |
|  |  |  |  | 164 | 55 | 80 | 4 |
|  |  |  |  | 168 | 48 | 80 | 2 |
|  |  |  |  | 172 | 53 | 80 | 4 |
|  |  |  |  | 172 | 55 | 80 | 4 |
|  |  |  |  | 176 | 53 | 80 | 4 |
|  |  |  |  | 176 | 55 | 80 | 4 |
|  |  |  |  | 180 | 48 | 80 | 8 |

The first section of the bytecode is a static value representing the subdivision of a quarter note into 4 ‘pulses’. Thus, all length and offset(tick) values are 4 \* the quarter note position.

The next section declares the instruments and their order in the note declaration body.

In the note declaration, each instrument gets four columns. For example, column 1 denotes the offset position for notes played by the first instrument and column 5 denotes offsets for the second instrument. Each note is given a row and allowed to specify an offset, pitch, loudness and length.

The bytecode is then compiled into a MIDI file. As MIDI files are not readable in binary form, I have not included the raw output, but a screenshot of the file executing in Garage Band can be found below:



## 6.3. Tests

|  |  |  |
| --- | --- | --- |
| Filename | Type | Output |
| test-hello.bach | Tests composition and measures generation. | A single instrument composition with one measure and one note. |
| test-empty.bach | Tests an empty instrument. | A valid composition with no notes. |
| Test-chord.bach | Tests use of chords in a measure | A composition with a two note chord |
| Test-chord-big.bach | Tests use of larger chords | A composition with a four note chord |
| Test-empty-meas.bach | Tests use of measures with no notes | A valid composition with two measures with notes and one measure without any. |
| Test-if.bach | Tests use of if statements | A valid composition based on input program |
| Test-inst.bach | Tests use of a different instrument | A composition with a Tenor Sax instrument |
| Test-len.bach | Tests changing the time signature | A composition with a measure length and time signature of 2 beats. |
| Test-loop.bach | Tests the loop construct | A composition with a measure repeated 4 times |
| Test-loop-rec.bach | Tests an embedded loop | A composition that repeats a measure progression 4 times. This progression also contains a measure that is repeated twice. |
| Test-mult.bach | Tests multiple measures | A composition that contains a sequence of two measures |
| Test-rest.bach | Tests rest notes | A composition with a measure that contains two one beat rests and two one beat notes. |
| Test-var.bach | Tests measure variable declaration and use | A compositon with two measures that are identical |
| Test-prog.bach | Tests the composition of features | A valid complex composition that adhears to all of the constructs used. |
| Test-chopstix.bach | Tests the composition of features | A valid composition that reflects the original song |

# 7. Lessons Learned

Because this was my first time working with Ocaml and it has many philosophical differences from my most used languages, it often took longer to write the code and get it running than I expected. Getting started earlier would have allowed me to work at a more reasonable pace by giving me a buffer to handle the Ocaml issues I ran into related to errors and debugging without running into deadlines. I found many of the error messages from Ocaml opaque and misleading, but this may be because of my inexperience with the language.

Also, looking at the lessons learned of future projects would be very helpful to do near the start of the project, rather than when you are writing your final report.

# 8. Appendix

The whole code repository and commit log is also available at:

https://github.com/sinflood/HOLLABACH

# 8.1. hollabach.ml