Music-Mike

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May 11, 2017

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1. **Introduction**

Western music is usually notated on a five-line staff, on which *notes* are given a *duration* based on symbol type, and *pitch* based on location in the staff. Composers can use proprietary software such as Sibelius or Finale to manipulate a virtual five-line staff through mouse clicks or keyboard gestures. Fans of computer music might instead use music synthesis libraries to programmatically create music in languages such as C++, but such libraries can be unintuitive for musicians unfamiliar with signals and waves.

We propose Music-mike, a compiled, strongly typed, programming language to give users an alternative option in music creation. Music-mike is designed for users to create music based on varied manipulations of short patterns. We owe this idea to Note Hashtag, a previous project completed in COMS W4115. However, unlike Note Hashtag, Music-mike is *modal* rather than *key-based.* Furthermore, lists - treated as the fundamental building block of music - are manipulated with special list operators (syntactic sugar) which create an intuitive interface based on traditional staff notation.

1.1 Design Ethos

The most basic unit in music is a *note*, which can be decomposed into pitch and duration. A simple melody can thus be described as two lists: one list of pitches and another of durations. A *chord* is a collection of notes played simultaneously.

A mapping of pitches is defined as a *mode.* All modes are subsets of the chromatic scale, which contains all twelve pitch classes used in Western music. Most music constrains the pitches of its notes to a small set of familiar modes, such as the major and minor scales. The sound of a *chord* is very much dependent on the *mode* that its notes come from.

Music-mike is based on the following observations regarding Western music: one, that Western music is fundamentally *chordal* and *modal.* Two, that Western music is repetitive and manipulative: simple building blocks of music are modified, then repeated multiple times in a piece. Finally, and most importantly, that these simple building blocks can described using lists and altered using a functional paradigm.

2. Language Tutorial

Basics

Let's try defining a variable first:

```
x = 5;
```

Now, let's write a function:

```
def AddFive a = a + 5;
```

Notice that we don't need to add any type annotations. Type inference handles everything for us. We can also write polymorphic functions, like the identity function:

```
def Identity x = x; y = Identity("Who am I"); Printstr(y);
```

Function calls require parentheses around arguments, but no commas to separate. For example:

```
def Add j k = j + k; sum = Add(4 5);
```

Note that arithmetic operators do not overload: we cannot pass in an floats to our Add function:

```
/* This fails!  */ wrong = Add(4.5 3);
```

A Musical Hello World

First we need to define a mode:

`/* A major scale */ major = [1 3 5 6 8 10 12 13];`

A rhythm list is defined with the r:[] constructor:

`r1 = r:[s s s s s s e s s s s s s e];`

A pitch list is defined with the p:[] constructor:

`p1 = p:[1 1 5 5 6 6 5 4 4 3 3 2 2 1];`

Now, we can generate a music string with the Synth function, which takes a pitch list, rhythm list, mode, start node, and channel:

`startnote = 50;`

`s = Synth(p1 r1 major startnote 1); /* Make_midi outputs a midi file */ Make_midi(s "twinkle.midi");`

And that is twinkle twinkle little star!

3. Language Reference Manual

3.1 Types, Operators, and Expressions

All types are immutable in Music-Mike.

3.1.1 Basic Types

- **Unit (unit)**

  The only value that unit can take is ().

- **Boolean (bool)**

  Takes two values: `true` or `false`.

- **Integer (int)**

  A 32-bit signed integer.

- **Float (float)**

  A 64-bit floating point number - follows the specifications of IEEE 754. Must contain a decimal point and either an integer or fractional component. The missing component is treated as a zero.

In the context of a rhythm list, floats can also be one of 6 characters that get scanned in as floats.

char	**float**
q	1,0
w	4.0
h	2.0
t	0.33
e	0.5
s	0.25

Examples: `5.  6.43 3.1415 .42 q e`

- **String (string)**

  A simple string enclosed by double quotations not spanning multiple lines.

  Examples: `"hello" "music mike looks good AND sounds good"`

- **Integer List**

  A list of 32-bit signed integers surrounded by square brackets `[ ]`, delimited by spaces.

  Examples: `[1 2 3 4] [57 0 65]`

- **Rhythm List**

  A list of 64-bit floating numbers and float characters (`q, w, h, t, e, s`) surrounded to the left by `r:[` and to the right by `]` and delimited by spaces. A Rhythm List is used to denote the length of each pitch/chord at each corresponding position in a Chord List.

Examples: `r:[0.5 .6 1.9 37.0]` `r:[q w s t]` `r:[.75 e s .09]`

- **Chord List**

  A list of chords. A chord cannot appear anywhere else. A chord is a list of one or more pitches delimited by a vertical bar |. A pitch is an integer pre-operated by zero or more ∧ and `v` s or post-operated by zero or more `b` or #. The chord list is delimited by spaces and surrounded to the right by `p:[` and to the left by `]`. A ∧ semantically represents an Octave Up. A `v` semantically represents an Octave Down. A `b` semantically represents a Flat. A # semantically represents a Sharp.

  Examples:

  ```
  p:[1 2 3]
  p:[1|3|5 5 6 7]
  p:[∧1|4|∧2# 5 v6|7|8###b## ]
  ```

3.2 Expressions

All expressions have return values in Music-Mike. An expression could be:

1. An integer, float or boolean literal constant:

c

2. A string constant enclosed by quotation marks

   “*string*”

3. An arithmetic operation:

   e_1 op e_2

4. An $if - then - else$ statement:

   `if` e_1 `then` e_2 `else` e_3

5. Variable declarations and assignment:

   $\mathbf{x} = e_1$

6. Variables:

   $\mathbf{x}$

7. A block of expressions. The last expression (e_n) is the value of the block:

   $\{e_1; e_2; \ldots e_{n-1}; e_n\}$

8. A Function Declarations. The name of the function starts with a Capital letter. The number of arguments n is greater than or equal to 0.

   `def` Fname $arg_1 \ldots arg_n = e$

9. Function call. The arguments are delimited by whitespace.

   Fname $(e_1 \ldots e_n)$

10. A white-space separated list of integers:

    `[`int_1 ... int_n`]`

11. A white-space separated list of floats and/or float characters:

    `r:[`$float_1$ ... $float_n$`]`

12. A white-space separated list of chords

    `p:[`$chord_1$ ... $chord_n$`]`

13. A concatenation of two list expressions:

    e_1 @ e_2

14. Subsetting a list:

    $e.[int]$

3.3 Variables and Assignment

Variable Identifiers in Music-Mike are strings that can be expressed using the regular expression:

```
['a' 'c'-'u' 'w'-'z'] | ['a' 'c'-'u' 'w'-'z']
['a'-'z' 'A'-'Z' '0'-'9' '_' ] *
```

Essentially, Variable Identifiers cannot start with a `b` or `v`.

Function Identifiers in Music-Mike are strings that can be expressed using the regular expression:

`['A'-'Z'] | ['A'-'Z']['a'-'z' 'A'-'Z' '0'-'9''_']*`

Essentially, Function Identifiers have to start with an Uppercase letter.

There are no type annotations in Music-mike due to use of the Hindley-Milner type system. We can assign a value to a variable using the following syntax:

`identifier = expr`

and type-inference will figure out the type. Note that the assignment operator is non-associative.

3.4 Operators

3.4.1 Arithmetic Operators

Binary arithmetic operators are strongly-typed; both operands must be of the same type, and use the correct operator for their type.

Binary integer operators in order of precedence: `* / + -` .

Binary float operators in order of precedence: `*.  /.  +.  -.`

3.4.2 Logical and Comparison Operators

Comparison operators support integers and floats; both operands must be of the same type:

`< > == !=`

The following boolean comparison operators are listed in order of precedence:

`== != && ||`

3.4.3 Pitch Operators

All pitch operators are unary. The postfix operators `'#' 'b'` raise or lower pitch by a half step. The prefix operators `'^' and 'v'` increment/decrement the octave of pitch by one.

3.4.4 List Operators

- Concatenation- One list followed by another of same type connected by an '@' symbol.

- Index- gets value of element of list using `.[]` operator

  `def Get_second x = x.[1]`

3.5 Control Flow

3.5.1 Statements

A statement is an expression followed by a semicolon.

3.5.2 Expressions

Expressions always have a return value. A constant expression returns its literal value, a variable expression returns the value in that variable. All of the list expressions return the list. Each of the expressions in a sequence of expressions has a value. Function declarations return the function itself as a value.

3.5.3 If-Then-Else

If statements are structured as `if` *`boolean-condition`* `then` *`expr`* `else` *`expr`*. If-Then-Else statements are themselves expressions and thus have return types. The expressions after `then` and `else` must have the same type.

```
fun iszero x = if x == 0 then true else false
```

3.5.4 Block

Blocks of code consist of semicolon delimited expressions and are enclosed by brackets ended by a semicolon.

3.6 Functions and Program Structure

3.6.1 Functions

Functions can be defined using the keyword `def`:

```
   def Name arg1 ...argN = expr
```

Note that the first character of a function's name has to be capitalized. Here's an example:

```
   def Plusfive x = x + 5;
```

We can also define our function to return more complex expressions:

```
fun Iszero x =
if x == 0 then true
else false
```

There is no function overloading in Music Mike. Declaring a different function of the same name is not legal. `Iszero 5.0` is not valid.

Functions are almost first-class citizens: they can be passed in as arguments to other functions and returned by functions, but user-defined functions cannot be nested. Thus we avoid the funarg problem and handling closure.

3.6.2 Built-in Functions

```
Printint Printstr Printfloat Printlist Printrlist
Synth Make_midi Merge
```

3.7 Comments

Comments are enclosed by $\backslash *\quad *\backslash$ There is no special single-line comment syntax, and nested comments are not supported.

3.8 Scoping

Once a variable has been defined, it cannot be redefined. All variables are stored in a global symbol table. In this sense Music-Mike is dynamically scoped.

3.9 Built in Functions

3.9.1 Printint

Given an integer value, prints it to standard output.

3.9.2 Printstr

Given a string value, prints it to standard output.

3.9.3 Printfloat

Given a float value, prints it to standard output.

3.9.4 Printlist

Given an integer list, prints it to standard output.

3.9.5 Printrlist

Given a rhythm list, prints it to standard output.

3.9.6 Synth

Takes a chord list, rhythm list, integer list (mode), integer starting note, and integer channel number, returns a CFugue string representation.

3.9.7 Merge

Takes two strings and returns them concatenated together.

3.9.8 Make_midi

Takes a CFugue string representation and a filename, generates the Midi file represented by that string and saves it.

4. Project Plan

4.1 Process

4.1.1 Planning

Our team met regularly twice a week on Wednesdays to meet with our TA Jacob Graff and on Sundays to work together as a team, debrief and set the course for the rest of the week. We used our Wednesday meetings as an opportunity to track and gauge our progress and also ask questions about difficult problems we came across during the previous week. We also talked about goals and milestones for the next Wednesday meeting and talked about any potential problems related to the difficulties of the goals we defined but also about any foreseeable road blocks related to tests, projects, other classes etc. that might hinder our progress. We used these meetings to make sure our project was progressing but also to shift our timeline to account for future roadblocks and delays.

4.1.2 Specifications

We spent the first three weeks deciding the specifications of our language. We all met near a piano either in the basement of the dorms or in Lerner and went over intuitive ways for musicians to express music. Once we chose how we wanted to abstract notes, pitches, chords, tempos and more, we started talking about how to structure our language. We initially chose to do a functional language modelled after OCaml, but as we progressed, we realized that for the use cases we were targeting a fully functional language wouldn't give us the kind of ease of use and usage we'd like. Our first concrete specifications were the abstractions and then we decided on syntax. Despite having a very concrete definition of specifications early on, we still changed specifications as we worked on our language when it was necessary to be able to finish within our timeline.

4.1.3 Development

Our team used github issues to define specifications and tasks that needed to be implemented or completed. We used github to help with organizing our development. Each of used a separate branch to develop the feature that we were working on and then submitted a pull request to the main branch once we thought it was ready. Then, another member of the team would review that request and merge the request. This ensured that all the code we pushed had been code reviewed and helped us maintain the quality of our mainline code.

4.1.4 Testing

We developed a test suite that tested individual components of the compiler. Every time one of us was working on a small component, we first wrote a test for how that component was supposed to work once it was finished. When writing In this regard, we used some principles of Test-First Programming to make sure we were preserving the functionality of the older features but also ensuring functionality of the new ones. While some of these tests were forward looking and failed early-on, the error messages told the developer whether we were making progress towards making these larger full stack tests work or if it was failing in whatever module the developer was working on.

4.2 Programming Style Guide

- Landin's pseudo law: Treat the indentation of your programs as if it determines the meaning of your programs. Keep indentation consistent with that of the MicroC code.
- Keep lines shorter than 80 characters.
- A function should always fit within one screenful (of about 70 lines), or in exceptional cases two, at the very most three. To go beyond this is unreasonable.

Justification: When a function goes beyond one screenful, it's time to divide it into subproblems and handle them independently. Beyond a screenful, one gets lost in the code. The indentation is not readable and is difficult to keep correct.

- The change in indentation between successive lines of the program is 2 spaces.
- Using the tab character (ASCII character 9) is absolutely not recommended. Change your .vimrc if you have tabs.
- Use underscores instead of Camel case

4.3 Timeline

Date	**Milestone**
Jan 29th	First commit to repository
Feb 8th	Project Proposal and White Paper Completed and Submitted
Feb 22	Language Reference Manual Completed and Submitted
Mar 21	Basic Scanner Complete
Mar 26	Basic AST and Parser Complete
Mar 29	Hello World runs
Apr 7	Testing Framework Complete
Apr 23	Final Scanner, Parser and AST Complete

4.3.1 Roles and Responsibilities

While we had defined project roles at the beginning of the semester, about three weeks in the roles became a lot more fluid. Our assigned roles were Tester, System Architect, Project Manager and Language Guru. Each member was involved in developing certain functionalities and portions of components. The team frequently worked together either in-person or teleconference.

Team Member	**Role**	Details
Husam Abdul-Kafi	Systems Architect	Code generation, Testing Architecture
Lakshmi Bodapati	Project Manager	Compiler Front-end, Documentation, Polymorphic Function Typing
Kaitlin Pet	Tester	Pitch and Chord Full Stack Abstraction, Library Linking, Testing Architecture
Harvey Wu	Language Guru	Type Inference, Compiler Front-end

4.3.2 Software Development Environment

1. Version Control: Git, Github
2. Languages: OCaml 4.04.0, C, Bash
3. Text Editor: Vim, Sublime Text, Atom
4. Operating System: Ubuntu 16.04, Mac OS X, Windows 10

5. Virtual Machine: Google Cloud

4.3.3 Project Log

05/10/17 11:25:27 C:\Users\husam\OneDrive\PLT\music-mike\log.log

```
c400293 was Harvey Wu, 35 minutes ago, message: Added stuff to Final Report
9f98afa was Harvey Wu, 44 minutes ago, message: Added fail on redefining stdlib functions
03489fb was Harvey Wu, 69 minutes ago, message: And more cleanup
447b852 was Harvey Wu, 70 minutes ago, message: More cleanup.:
356bda2 was Harvey Wu, 2 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
dc595a1 was Harvey Wu, 2 hours ago, message: Lots of cleanup. Style issues. More tests.
db9c39d was Mounika, 2 hours ago, message: Merge pull request #78 from wuharvey/documentation
98c5e80 was Lakshmi Bodapati, 2 hours ago, message: completed first draft. Needs to be latexed and Appendix filled out and personal reflections filled out and codegen section. Other sections either need diagrams or examples. LRM needs to be updated and made a part of this document
9945ce8 was habdulkafi, 2 hours ago, message: added test script
23c2de9 was Lakshmi Bodapati, 2 hours ago, message: added in more details about modules
4915533 was Lakshmi Bodapati, 3 hours ago, message: presentation ppt and pdf
c62f155 was Harvey Wu, 4 hours ago, message: Important stuff for presentation
84101fc was Harvey Wu, 4 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
4973127 was kpet123, 5 hours ago, message: Merge pull request #77 from wuharvey/husam-synth-new
99acf48 was Harvey Wu, 5 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
1f9059e was Harvey Wu, 5 hours ago, message: Fixed semant
ef13d4f was kpet, 5 hours ago, message: yay!
b0edb37 was habdulkafi, 5 hours ago, message: stuff
ecd6017 was Husam Abdul-Kafi, 6 hours ago, message: Merge pull request #76 from wuharvey/synth-2
75725c1 was Husam Abdul-Kafi, 6 hours ago, message: Merge branch 'master' into synth-2
c11f8db was kpet, 6 hours ago, message: fixed make midi
```

```
8fa796c was kpet, 6 hours ago, message: Merge branch 'synth-2' of https://github.com/wuharvey/music-mike into synth-2
e867c0d was kpet, 6 hours ago, message: test worksgit add ../testall.sh
b02e6de was habdulkafi, 6 hours ago, message: updated cfugue exe w/ cmd line args
f90fd79 was Husam Abdul-Kafi, 7 hours ago, message: Merge pull request #75 from wuharvey/husam-strcat
e37d735 was habdulkafi, 7 hours ago, message: added string concatenation
47d4f11 was Husam Abdul-Kafi, 7 hours ago, message: Merge pull request #74 from wuharvey/semant-mounika
8ec4c14 was habdulkafi, 7 hours ago, message: fixed deleting of non-poly funs
743bdf9 was kpet, 7 hours ago, message: swithcing branches changed synth to read channels
e1cc90a was Harvey Wu, 8 hours ago, message: Removed wrong tests
68ebe67 was Lakshmi Bodapati, 8 hours ago, message: Merge branch 'synth-2' of https://github.com/wuharvey/music-mike into synth-2
0f12965 was Lakshmi Bodapati, 8 hours ago, message: makemidi c
2d1f56a was Harvey Wu, 8 hours ago, message: Inference for blocks
fb03be5 was Mounika, 8 hours ago, message: parens fixes
9a986d8 was Lakshmi Bodapati, 8 hours ago, message: make_midi Mounika changes, testing on cloud
5076048 was Husam Abdul-Kafi, 8 hours ago, message: Merge pull request #73 from wuharvey/master
f5bc384 was Harvey Wu, 9 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
c1f4047 was Harvey Wu, 9 hours ago, message: FIXED! INFER IS BACK TO NORMAL
1174871 was Harvey Wu, 9 hours ago, message: Debugging printing for Chord
83c5206 was Harvey Wu, 9 hours ago, message: Fixing inference
c266d3d was kpet123, 9 hours ago, message: Merge pull request #71 from wuharvey/junk-branch
f730a08 was habdulkafi, 9 hours ago, message: Merge branch 'semant-mounika' of https://github.com/wuharvey/music-mike into semant-mounika
4c0c348 was Husam Abdul-Kafi, 9 hours ago, message: Merge pull
```

```
request #70 from wuharvey/husam-functions
9fe34be was kpet, 9 hours ago, message: rests should work now
cfd68b9 was Harvey Wu, 9 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
212208b was Harvey Wu, 9 hours ago, message: Merge pull request #69 from wuharvey/semant-mounika
596ac10 was Harvey Wu, 10 hours ago, message: Merge branch 'semant-mounika' of https://github.com/wuharvey/music-mike into semant-mounika
dc907df was Harvey Wu, 10 hours ago, message: Semant testing
adafd38 was Mounika, 10 hours ago, message: project proposal update
6a192d9 was habdulkafi, 10 hours ago, message: fixed order of arguments in function decls
75b28b4 was Mounika, 10 hours ago, message: Harvey's infer
1451ec9 was habdulkafi, 10 hours ago, message: FUNCTIONS HERE WE COME
07a857f was Mounika, 10 hours ago, message: semant fixed
0712686 was kpet, 10 hours ago, message: sorry on master
2573816 was Harvey Wu, 11 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
1b1a4b5 was habdulkafi, 11 hours ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
e3e17bf was habdulkafi, 11 hours ago, message: fixed up tests
037d186 was Mounika, 11 hours ago, message: Merge pull request #68 from wuharvey/semant
1235262 was Husam Abdul-Kafi, 23 hours ago, message: Merge pull request #67 from wuharvey/synth-in-codegen
30ae318 was habdulkafi, 23 hours ago, message: added new exe file (no idea if its different
36e5725 was habdulkafi, 24 hours ago, message: fixed length of rhythm
e2a2a0c was habdulkafi, 24 hours ago, message: debugging print statements everywhere
f47e2f6 was habdulkafi, 24 hours ago, message: added stuff we were missing
226bb6e was habdulkafi, 25 hours ago, message: changed test file
2592a3e was habdulkafi, 25 hours ago, message: commented out main.  debugging prints
eb641c2 was habdulkafi, 25 hours ago, message: added chordlengths
67  3169529 was habdulkafi, 25 hours ago, message: fixed up
    testall so it links properly
68  3f15a4f was habdulkafi, 27 hours ago, message: IT ALMOST
    WORKS.  IT'S NOT LINKING PROPERLY
69  883c57b was habdulkafi, 28 hours ago, message: trying to fix
    synth in codegen
70  febce5f was habdulkafi, 32 hours ago, message: changed around
    a bunch of types
71  0ab1fae was habdulkafi, 32 hours ago, message: reversed call
    list
72  23d0d51 was habdulkafi, 32 hours ago, message: switched floats
    to doubles
73  93e322e was kpet123, 32 hours ago, message: Merge pull request
    #66 from wuharvey/test-cases
74  f1860c3 was kpet, 32 hours ago, message: more test cases
75  322fa4a was kpet, 33 hours ago, message: added new error cases
76  6b047ec was kpet, 33 hours ago, message: made more fail tests
    cases
77  a313859 was habdulkafi, 2 days ago, message: fixed up
    assignment of rhythm list and codegen for chord list
78  364dd81 was habdulkafi, 2 days ago, message: fixed up some
    tests
79  21f3e5e was habdulkafi, 2 days ago, message: added more
    expressive error messages for some errors
80  033c0bb was habdulkafi, 2 days ago, message: added printing
    for rhythm list
81  189ef73 was kpet, 2 days ago, message: pushing compiling
    branch
82  6b0ba65 was Harvey Wu, 2 days ago, message: Merge branch
    'master' of https://github.com/wuharvey/music-mike
83  6015176 was kpet, 2 days ago, message: switching branches
    (refactored chord list ), need to test *)
84  9e50a35 was habdulkafi, 2 days ago, message: Merge branch
    'master' of https://github.com/wuharvey/music-mike
85  932a181 was habdulkafi, 2 days ago, message: added pretty
    printing for expr(Fun())
86  3611c25 was Husam Abdul-Kafi, 2 days ago, message: Merge pull
    request #65 from wuharvey/semant-mounika
87  901d757 was Husam Abdul-Kafi, 2 days ago, message: Merge pull
    request #64 from wuharvey/revert-63-semant-mounika
88  1052c70 was Husam Abdul-Kafi, 2 days ago, message: Revert
    "Semant mounika"
```

```
01d3abc was Husam Abdul-Kafi, 2 days ago, message: Merge pull request #63 from wuharvey/semant-mounika
683951c was habdulkafi, 2 days ago, message: added printing for functions
be2a32e was Lakshmi Bodapati, 2 days ago, message: @
38a5f0b was Mounika, 2 days ago, message: Merge pull request #62 from wuharvey/LRM-edits
737bad0 was Lakshmi Bodapati, 2 days ago, message: aexpr list vs. aexpr problem
afad984 was Lakshmi Bodapati, 2 days ago, message: compile fixes
85e28ab was Lakshmi Bodapati, 2 days ago, message: all the logic is here?
17fb20f was Harvey Wu, 2 days ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
da24b60 was Lakshmi Bodapati, 2 days ago, message: semant with husam
352a82b was Lakshmi Bodapati, 2 days ago, message:  need to replace Afun dummy with Afun with types using the polycalls. Struggling with syntax for mapping Acall to Afun with correct types
758f93b was kpet, 2 days ago, message: pushing
fa93632 was kpet, 2 days ago, message: pushing branch, inference doesn't work with other stuff
bef71bb was Harvey Wu, 2 days ago, message: Starting semantic checker.
69a145f was kpet, 2 days ago, message: going to switch out files from inference
26839b9 was kpet, 2 days ago, message: mergeMerge branch 'synth-in-codegen' of https://github.com/wuharvey/music-mike into synth-in-codegen
0aadc40 was Mounika, 3 days ago, message: remove Midi test output
14870da was Mounika, 3 days ago, message: Merge pull request #61 from wuharvey/synth-make
9037ae0 was Mounika, 3 days ago, message: working Makefile that produces synth.o
1f0c93a was Lakshmi Bodapati, 3 days ago, message: make file mimic microC
374bf36 was kpet, 3 days ago, message: nice version of actual operators
b1166e9 was kpet, 3 days ago, message: synth in codegen
```

```
compiles, still needs testing
fc86caa was kpet, 3 days ago, message: getting weird area for
internal map function
23b19d6 was kpet, 3 days ago, message: switching branches
ec236fa was kpet, 3 days ago, message: generalized map
function
72bf5bb was Harvey Wu, 3 days ago, message: Updated Final
Report, changed style stuff.
196982f was kpet, 3 days ago, message: need to change branches
0bc072e was Harvey Wu, 3 days ago, message: Merge branch
'master' of https://github.com/wuharvey/music-mike
31ac72f was kpet, 4 days ago, message: added pointer list
structs
0969b09 was kpet, 4 days ago, message: yesMerge branch
'master' of https://github.com/wuharvey/music-mike
d8184b5 was Husam Abdul-Kafi, 4 days ago, message: Merge pull
request #58 from wuharvey/midi
047f260 was Harvey Wu, 4 days ago, message: Merge branch
'master' of https://github.com/wuharvey/music-mike
2bcb519 was habdulkafi, 4 days ago, message: Merge branch
'midi' of https://github.com/wuharvey/music-mike into midi
da8fb62 was habdulkafi, 4 days ago, message: commented the big
print function
e079301 was Mounika, 4 days ago, message: Merge pull request
#57 from wuharvey/midi
145e728 was Lakshmi Bodapati, 4 days ago, message: fixing
oopsie
6c5ea40 was Lakshmi Bodapati, 4 days ago, message: remove midi
68bd854 was Lakshmi Bodapati, 4 days ago, message: Merge
remote-tracking branch 'origin' into midi
dc21ddb was Lakshmi Bodapati, 4 days ago, message: oops and
CFugue deleted
76f8e19 was Lakshmi Bodapati, 4 days ago, message: remove
CFugue repos
984d4d7 was Mounika, 4 days ago, message: compiling synth with
the executable to produce the Midi thingy
4dce401 was Lakshmi Bodapati, 4 days ago, message: synth slash
fix
20b593d was Mounika, 4 days ago, message: song
5a4001d was Mounika, 4 days ago, message: C testing
4df745d was Mounika, 4 days ago, message: testing
751ae46 was Mounika, 4 days ago, message: C fixeseseseses
```

```
134  64187be was Lakshmi Bodapati, 4 days ago, message: synth to
     linux
135  e7e9dab was Harvey Wu, 4 days ago, message: Merge branch
     'master' of https://github.com/wuharvey/music-mike
136  a6af71b was habdulkafi, 4 days ago, message: Merge branch
     'master' of https://github.com/wuharvey/music-mike
137  924378f was habdulkafi, 4 days ago, message: fixed subset?
138  f6b78ef was Harvey Wu, 4 days ago, message: Merge branch
     'master' of https://github.com/wuharvey/music-mike
139  0de5779 was Harvey Wu, 4 days ago, message: Fixed subset to
     type typeof return
140  97072a9 was Lakshmi Bodapati, 4 days ago, message: execl
141  f1c6b92 was Mounika, 4 days ago, message: Merge pull request
     #56 from wuharvey/final_report
142  d1e8865 was Lakshmi Bodapati, 4 days ago, message: Merge
     branch 'master' of https://github.com/wuharvey/music-mike into
     midi
143  ec8969f was Husam Abdul-Kafi, 4 days ago, message: Merge pull
     request #55 from wuharvey/husam-struct-arrays
144  791c766 was habdulkafi, 4 days ago, message: added more
     expressive not found error + took away list.rev
145  ad3a012 was habdulkafi, 4 days ago, message: fixed list type
     to be struct
146  86db086 was habdulkafi, 4 days ago, message: added Printlist
     function type
147  0ab3584 was Husam Abdul-Kafi, 4 days ago, message: Merge
     branch 'master' into husam-struct-arrays
148  d14caa9 was kpet, 4 days ago, message: getting updated
     versionMerge branch 'master' of
     https://github.com/wuharvey/music-mike
149  db8cc19 was kpet123, 4 days ago, message: Create synth.c
150  56dad56 was Harvey Wu, 5 days ago, message: Subset type
     inference
151  359d996 was Harvey Wu, 5 days ago, message: Useless commit
152  2f89a3d was Harvey Wu, 5 days ago, message: Debug information
     for inference only printed with -s flag. Added rhythm list
     inference
153  3666fa4 was Mounika, 6 days ago, message: duration syntax
154  6b9e414 was Mounika, 6 days ago, message: added brackets to
     numbers
155  fa0f431 was Mounika, 6 days ago, message: trying out numerical
     random chords 62q+65q+123q 3a+4h+8h
```

```
156  51fe8da was Mounika, 6 days ago, message: testing a chord
157  ed4eb40 was Harvey Wu, 6 days ago, message: Codegen takes
     AEXPR instead of EXPR now.
158  55d53cc was Harvey Wu, 6 days ago, message: Merge branch
     'master' of https://github.com/wuharvey/music-mike
159  7f1e9fd was Harvey Wu, 6 days ago, message: Merge pull request
     #54 from wuharvey/inference
160  8d25ebc was Harvey Wu, 6 days ago, message: merge
161  75595a0 was Harvey Wu, 6 days ago, message: Trying to set up
     flags for debug messages
162  e612a0e was Harvey Wu, 6 days ago, message: Merge branch
     'inference' of https://github.com/wuharvey/music-mike into
     inference
163  2c84db9 was Harvey Wu, 6 days ago, message: Update function
     types in environment
164  0f8ae1f was Harvey Wu, 6 days ago, message: Type inference for
     functions.
165  c152c94 was habdulkafi, 6 days ago, message: fixed subset into
     list.  added markings for where work is actually being done in
     iter through list
166  3633d86 was habdulkafi, 6 days ago, message: GOT LLVM PRINTING
     OF A LIST TO WORK
167  b3b4c09 was Harvey Wu, 7 days ago, message: (Almost) no lines
     wrap over 80 chars now.
168  e6254cb was Harvey Wu, 7 days ago, message: Merge branch
     'master' into inference
169  8da11fa was Harvey Wu, 7 days ago, message: Added Chord type
     to ast
170  d0983f1 was Harvey Wu, 7 days ago, message: Added Keyword Set,
     Assign inference, style tweaks to infer.ml. Corrected the
     order of inference. TODO: Replace dummy type in env after
     Assign.
171  563f853 was Harvey Wu, 7 days ago, message: Fixed some stuff
     for strings and pretty printing
172  8209193 was Harvey Wu, 7 days ago, message: Changed pretty
     printing to aid debugging. Fixed list inference
173  611e202 was habdulkafi, 7 days ago, message: fixed up sample
     app so it takes cmd line args
174  4869072 was Mounika, 7 days ago, message: sample ap changes
     that aren't compiling
175  66abc45 was Mounika, 7 days ago, message: Mounika testing
     stuff
```

```
176  704eb76 was Harvey Wu, 8 days ago, message: Added parentheses
     for prec escalation
177  9286291 was Harvey Wu, 8 days ago, message: Type inference
     works for If statements
178  3e2779f was habdulkafi, 8 days ago, message: fixed simple
     printing error
179  fb53591 was habdulkafi, 8 days ago, message: added pretty
     printing for chordlist
180  93e4360 was Harvey Wu, 8 days ago, message: Added lib.ml for
     stdlib. Changed Makefile to include lib. Modified musicmike.ml
     to take -s flag to test type inference. Related changes.
181  005a03b was habdulkafi, 8 days ago, message: changed structure
     to only take expressions
182  04ee773 was habdulkafi, 8 days ago, message: messed with ID
     wrt Call and Fun
183  7c9cb0f was habdulkafi, 8 days ago, message: fixed up codegen
     wrt function definitions
184  6391ab6 was Harvey Wu, 8 days ago, message: make frontend
     compiles now
185  3f32795 was Harvey Wu, 8 days ago, message: Merge pull request
     #53 from wuharvey/infer
186  d445d78 was Harvey Wu, 8 days ago, message: Merge branch
     'master' into infer
187  66187ed was Harvey Wu, 8 days ago, message: Added pretty
     printing for aexprs to AST
188  0e3f7a4 was Harvey Wu, 9 days ago, message: Changed Makefile
     and musicmike.ml
189  682765a was Harvey Wu, 10 days ago, message: Inference module
     now compiles. Changed fdecl in parser. Minor modifications to
     ast.ml
190  be3a01f was Harvey Wu, 2 weeks ago, message: Added stuff to
     infer. Got rid of user defined types.
191  192ea8d was Harvey Wu, 2 weeks ago, message: Added more stuff
     to infer.
192  3db649f was Lakshmi Bodapati, 2 weeks ago, message: Wrote more
     stuff for type inference.
193  ec47966 was Harvey Wu, 2 weeks ago, message: Did a shit ton of
     stuff yo don't even remember what i did
194  252748e was Mounika, 2 weeks ago, message: Merge pull request
     #37 from wuharvey/music-operators
195  9b25747 was kpet, 2 weeks ago, message: hacked rhythmlist
196  8ded65a was Lakshmi Bodapati, 2 weeks ago, message: TestPlan
```

```
197  cb5883d was Mounika, 2 weeks ago, message: Merge branch
     'master' into music-operators
198  14c150c was Lakshmi Bodapati, 2 weeks ago, message:
     architecture section
199  a198521 was Lakshmi Bodapati, 2 weeks ago, message: I tried to
     somehow define what each of us worked on but it's kinda hard
     since we didn't do it by an assigned module basis like other
     groups seemed to have
200  a069108 was kpet, 2 weeks ago, message: changed name of
     pitchlist to chordlist
201  91b29a7 was kpet, 2 weeks ago, message: added empty rhythm
     test
202  8d03848 was kpet, 2 weeks ago, message: compiles- rhythmlist
203  2b2e880 was kpet, 2 weeks ago, message: added bar to scanner
204  b41299f was Lakshmi Bodapati, 2 weeks ago, message: rough
     roles and responsibilities portion
205  a8c239a was Lakshmi Bodapati, 2 weeks ago, message: Timeline
206  16fac51 was Lakshmi Bodapati, 2 weeks ago, message: finished
     project process and style guide
207  820e911 was Mounika, 2 weeks ago, message: Merge pull request
     #36 from wuharvey/mounika_semant
208  0e52b05 was Lakshmi Bodapati, 2 weeks ago, message: mergeMerge
     branch 'master' of https://github.com/wuharvey/music-mike into
     mounika_semant
209  6dc6478 was Lakshmi Bodapati, 2 weeks ago, message:
     Specifications
210  62f7662 was kpet, 2 weeks ago, message: the last one didn't
     work- getting weird error : Scanner.is_pat ref ->
     Lexing.lexbuf -> Parser.token
211  8742ef2 was kpet, 2 weeks ago, message: fixed indexing error
212  4b3f962 was kpet, 2 weeks ago, message: it comiles! pitches as
     expressions
213  7223852 was kpet, 2 weeks ago, message: getting weird bug in
     codegen pitches: Error: This expression has type int *
     'a        but an expression was expected of type 'b * 'c * 'd
214  9083b6d was Lakshmi Bodapati, 2 weeks ago, message: project
     plan halfway done
215  d89d880 was Lakshmi Bodapati, 2 weeks ago, message: added
     stuff we need from proposal
216  00e650b was kpet, 2 weeks ago, message: merging with scanner
     changes Merge branch 'master' of
     https://github.com/wuharvey/music-mike
```

```
ac99249 was kpet, 2 weeks ago, message: forgot these
ba681f3 was kpet, 2 weeks ago, message: implemented rlist in
codegen, need to sync with semant
3d63c44 was Husam Abdul-Kafi, 2 weeks ago, message: Merge pull
request #35 from wuharvey/husam-if-stmnt
76f6c38 was habdulkafi, 2 weeks ago, message: added tests for
basic if statements
dd129df was habdulkafi, 2 weeks ago, message: added basic if-
then-else functionality
f3dbb5a was kpet, 2 weeks ago, message: llvm seems to be
working
6fd77a5 was kpet, 2 weeks ago, message: it compiles!
6533bcd was kpet, 2 weeks ago, message: changed orientation
again (inner functions sandwiched between mallocs and iters)
3e1b780 was habdulkafi, 2 weeks ago, message: added basic test
for function call
24d5cd3 was habdulkafi, 2 weeks ago, message: added basics of
function calls
408867d was habdulkafi, 2 weeks ago, message: got rid of
reduce/reduce conflicts.  added ability to have 0 params fun
def and fun calls
3ad1502 was kpet, 2 weeks ago, message: pushing code
fe06d32 was kpet, 2 weeks ago, message: modified version of
pitch list no syntax errors at least
787b2e4 was Mounika, 2 weeks ago, message: Merge pull request
#33 from wuharvey/mounika_semant
1e3e04c was Mounika, 2 weeks ago, message: change FID
a922768 was Mounika, 2 weeks ago, message: Merge pull request
#32 from wuharvey/mounika_semant
9fc77c3 was Mounika, 2 weeks ago, message: test output
671efd8 was Mounika, 2 weeks ago, message: add rhythm test
file
47e260c was Mounika, 2 weeks ago, message: parsing error now!
315da1f was kpet, 2 weeks ago, message: simplified pitch
+ast.ml
45418dd was kpet, 2 weeks ago, message: simplitifed pitch
a78bcf8 was Mounika, 2 weeks ago, message: compiles
5aab008 was Mounika, 3 weeks ago, message: sorta
working...can't quite debug
aab45ba was Lakshmi Bodapati, 3 weeks ago, message: change
call to scanner
cfce11d was Lakshmi Bodapati, 3 weeks ago, message: parse
```

```
     rhythm separately
242  f8d1851 was kpet, 3 weeks ago, message: reformatted list.iteri
243  5d04360 was kpet, 3 weeks ago, message: changing to master
244  4d73d55 was kpet, 3 weeks ago, message: let-in doesn't match,
     tried reducing problem to list of lists
245  caf80ac was kpet, 3 weeks ago, message: fixed indices
246  9fe5bab was kpet, 3 weeks ago, message: second crack, now at
     least code makes some sense
247  75e8944 was kpet, 3 weeks ago, message: implemented pitch list
     still need to test  :'(
248  41b3ba4 was kpet, 3 weeks ago, message: working on pitchlist
249  9d1edd2 was habdulkafi, 3 weeks ago, message: fixed up pitch
     list in parser, ast. commented out pitch list in codegen for
     now
250  9db67f2 was kpet, 3 weeks ago, message: codegen attempt to
     parser pitch list
251  feffec9 was kpet, 3 weeks ago, message: annotated parser.
     Issues:cannot have empty lists
252  210e481 was kpet, 3 weeks ago, message: it compilesgit add
     parser.mly ast.mlgit add parser.mly ast.mlgit add parser.mly
     ast.ml!
253  604a686 was kpet, 3 weeks ago, message: getting weird error:
     This expression has type Ast.chord = Ast.pitch list        but
     an expression was expected of type          Ast.pitch = int
     list * int * int list
254  4033493 was kpet, 3 weeks ago, message: working on ast/parser
     structure
255  dd8124c was kpet, 3 weeks ago, message: scanner and parser
     with logically consistant updates
256  ccc12d7 was kpet, 3 weeks ago, message: restructured parser so
     pitches easier to access
257  62afa61 was kpet, 4 weeks ago, message: changed parser and ast
258  3bb8123 was kpet, 4 weeks ago, message: added operations in
     codegen
259  5580c7b was kpet, 4 weeks ago, message: first commit in pitch
     operation edits
260  dd6a056 was kpet, 4 weeks ago, message: added LRM and edited
     some parts
261  f864f7a was kpet, 4 weeks ago, message: nothing worth saving
     on Kaitlin end Merge branch 'master' of
     https://github.com/wuharvey/music-mike
262  c5ea544 was kpet, 4 weeks ago, message: saving codegen and
```

```
scanner so can pull
e28b6bf was Husam Abdul-Kafi, 4 weeks ago, message: Merge pull
request #31 from wuharvey/husam-fun-decl
a15e49d was habdulkafi, 4 weeks ago, message: added basic
function declaration codegen and test file
7e7563e was Harvey Wu, 4 weeks ago, message: Removed mike-
files directory.
99be096 was Lakshmi Bodapati, 4 weeks ago, message: scanner
change
2a534f0 was Lakshmi Bodapati, 4 weeks ago, message: testing
syntax
4fd20f3 was Lakshmi Bodapati, 4 weeks ago, message: more tests
e91f565 was Lakshmi Bodapati, 4 weeks ago, message: test
97e9950 was Lakshmi Bodapati, 4 weeks ago, message: testing
4f6c493 was Lakshmi Bodapati, 4 weeks ago, message: oopsie
afea966 was Lakshmi Bodapati, 4 weeks ago, message: testing
3316a04 was Lakshmi Bodapati, 4 weeks ago, message: scanner
426d243 was Lakshmi Bodapati, 4 weeks ago, message: new
approach
ff3495f was Lakshmi Bodapati, 4 weeks ago, message: add seed
for rhythm list
86d53dd was Lakshmi Bodapati, 4 weeks ago, message: parser
compiles with no conflicts
15b8b06 was Lakshmi Bodapati, 4 weeks ago, message: Rlist
254bda2 was Lakshmi Bodapati, 4 weeks ago, message: changed
parser and scanner to scan in rhythm list
58149cc was Husam Abdul-Kafi, 4 weeks ago, message: Merge pull
request #30 from wuharvey/husam-fun-def
8e59d52 was habdulkafi, 4 weeks ago, message: added test to
test block return
ddafd82 was habdulkafi, 4 weeks ago, message: reversed list of
exprs in block
da614ff was habdulkafi, 4 weeks ago, message: added code
generation for blocks
8ab5162 was Husam Abdul-Kafi, 4 weeks ago, message: Merge pull
request #29 from wuharvey/husam-fun-def
bf36fe8 was habdulkafi, 4 weeks ago, message: fixing
differences in the merge
b7aebef was habdulkafi, 4 weeks ago, message: added parens in
fn calls.  fixed test files for prints
beb578e was kpet123, 4 weeks ago, message: Update parser.mly
366d161 was kpet123, 4 weeks ago, message: Merge pull request
```

```
     #28 from wuharvey/temp
288  a63dc12 was kpet, 4 weeks ago, message: deleted test files
289  99220ce was Harvey Wu, 4 weeks ago, message: Merge branch
     'mounika_semant' of https://github.com/wuharvey/music-mike
     into mounika_semant
290  ec5900a was Harvey Wu, 4 weeks ago, message: removed EOF
291  0de0e08 was kpet, 4 weeks ago, message: added test files
292  4cdc308 was Harvey Wu, 4 weeks ago, message: Corrected
     spelling for RList
293  d89408f was Lakshmi Bodapati, 4 weeks ago, message: make
     uppercase in ast
294  a4dba31 was Lakshmi Bodapati, 4 weeks ago, message: pretty
     print rhythm list
295  ad48a09 was Lakshmi Bodapati, 4 weeks ago, message: ast to
     include rhythm list
296  f45108c was Lakshmi Bodapati, 4 weeks ago, message: mounika
     list attempts
297  3c8db43 was Lakshmi Bodapati, 4 weeks ago, message: possible
     working scanner lists?
298  bf2a686 was habdulkafi, 4 weeks ago, message: added ; in
     parser and beginning of function declarations in codegen.  BAD
     STATE
299  c269baa was habdulkafi, 4 weeks ago, message: changed test
     files to have ;
300  cee5ee9 was Lakshmi Bodapati, 4 weeks ago, message: merge
     Merge branch 'master' of https://github.com/wuharvey/music-
     mike into mounika_semant
301  d18378f was Lakshmi Bodapati, 4 weeks ago, message: fix all
     function calls
302  230d8ca was Harvey Wu, 4 weeks ago, message: Updated string
     stuff for scanner
303  e561352 was Lakshmi Bodapati, 4 weeks ago, message: L and R
     paren stuff + fixed a bad merge
304  f332007 was Lakshmi Bodapati, 4 weeks ago, message: merged
305  32531a9 was Lakshmi Bodapati, 4 weeks ago, message:
     parenthesis to functions compiles with I just make the parser
306  647e542 was Lakshmi Bodapati, 4 weeks ago, message: add
     parenthesis to parsing function calls
307  22b3205 was Lakshmi Bodapati, 4 weeks ago, message: commenting
     out stuff I don't think we need
308  3341ebd was habdulkafi, 4 weeks ago, message: fixed up error
     files for tests.  modified codegen to output error
```

```
f10564c was habdulkafi, 5 weeks ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike i'm not sure what's going on..
4f3c550 was habdulkafi, 5 weeks ago, message: fixed issue #26 !  added a list.rev to exprs list.  fixed test cases
d8fd50e was Husam Abdul-Kafi, 5 weeks ago, message: Merge pull request #27 from wuharvey/husam-arrays
1800b54 was habdulkafi, 5 weeks ago, message: added subsetting to codegen and test files
54314d8 was habdulkafi, 5 weeks ago, message: elements in the list were reversed - fixed now.  fixed subsetting
1c2759c was habdulkafi, 5 weeks ago, message: added .[ to scanner
7a2ca69 was habdulkafi, 5 weeks ago, message: changed Sub --> Subset
07ad1e3 was habdulkafi, 5 weeks ago, message: assigning arrays to variables works now
550072e was habdulkafi, 5 weeks ago, message: fixed up assignment and lookup using a hash table
bde3c88 was habdulkafi, 5 weeks ago, message: added SEMI after assignment.  The output of the parser is still wrong - the expressions are reverse order
26bb9f2 was habdulkafi, 5 weeks ago, message: added tests that *shouldn't fail (but they do)
e74a42a was habdulkafi, 5 weeks ago, message: added verbose output to Makefile
4e3e4d7 was habdulkafi, 5 weeks ago, message: added start of array implementation
d99dd56 was habdulkafi, 6 weeks ago, message: fixed up test files, merged codegen
e821cc8 was habdulkafi, 6 weeks ago, message: fixed float printing. added assignment
bc5e576 was Harvey Wu, 6 weeks ago, message: Merge pull request #25 from wuharvey/Harvey-Codegen2
0469af1 was Husam Abdul-Kafi, 6 weeks ago, message: Merge pull request #24 from wuharvey/Harvey-Codegen1
7aed9be was habdulkafi, 6 weeks ago, message: fixed up codegen and added test set-up
8da1996 was Harvey Wu, 6 weeks ago, message: Added float printing to Codegen. Added test files.
d648034 was Harvey Wu, 6 weeks ago, message: Merge branch 'Harvey-Codegen1' of https://github.com/wuharvey/music-mike
```

```
     into Harvey-Codegen1
329  423ce70 was habdulkafi, 6 weeks ago, message: HELLO WORLD
     WORKSgit statusgit status!
330  fbaaab2 was Harvey Wu, 6 weeks ago, message: Merge branch
     'Harvey-Codegen1' of https://github.com/wuharvey/music-mike
     into Harvey-Codegen1
331  2dec649 was habdulkafi, 6 weeks ago, message: p-->P simple
     makefile edit
332  d01e532 was Harvey Wu, 6 weeks ago, message: Merge branch
     'Harvey-Codegen1' of https://github.com/wuharvey/music-mike
     into Harvey-Codegen1
333  4218f5d was Harvey Wu, 6 weeks ago, message: Changed to
     capital P
334  4ea71f2 was Mounika, 6 weeks ago, message: fix syntax for far
     away test file
335  ac8bd84 was Mounika, 6 weeks ago, message: test file syntax
     fixes
336  b040d13 was Harvey Wu, 6 weeks ago, message: Renamed microc ->
     musicmike in Makefile and .ml file. Added more stuff to
     codegen while maintaining compilability
337  83b0bd5 was Harvey Wu, 6 weeks ago, message: Update README.md
338  1bf659d was Harvey Wu, 6 weeks ago, message: Merge pull
     request #21 from wuharvey/Harvey-Codegen1
339  fa036e9 was habdulkafi, 6 weeks ago, message: added string
     conversion to ast file
340  30f25d5 was habdulkafi, 6 weeks ago, message: codegen is all
     commented out, but general structure of what we want is still
     there
341  6d9d337 was habdulkafi, 6 weeks ago, message: commented out
     unused tokens cause it complained about them being unused
342  08e6e29 was habdulkafi, 6 weeks ago, message: added ocamlbuild
     workaround so it compiles on my system
343  9ea5b9a was habdulkafi, 6 weeks ago, message: added the
     microc.ml file (unchanged).  added semant.ml file w/ all of it
     commented out and it returns unit()
344  d9e92e0 was Harvey Wu, 6 weeks ago, message: Removed
     irrelevant things in codegen.
345  03e16b2 was Harvey Wu, 6 weeks ago, message: Added more
     pattern matching to type expr in AST.
346  68cf1e4 was Harvey Wu, 6 weeks ago, message: Added auxillary
     functions for 3-tuple in header. Changed high-level structure
```

```
of grammar to lists of expressions, fdecls, and tdecls. Added assign_list to specify lists of assignments for tdecl.
63fd50e was Harvey Wu, 6 weeks ago, message: Added make command for parser/ast combination compilation
94e0249 was Harvey Wu, 7 weeks ago, message: Removed statement from ast and added relevant types to EXPR. Fixed small issues in parser.
6bf70cc was Harvey Wu, 7 weeks ago, message: Added Makefile (only use currently is make clean)
60c03ac was Harvey Wu, 7 weeks ago, message: Merged codegen edits with master
132db13 was Harvey Wu, 7 weeks ago, message: Cleaned up Codegen, minor modifications to parser/scanner
032ee30 was Lakshmi Bodapati, 7 weeks ago, message: repo organization
77266ae was Kaitlin Pet, 7 weeks ago, message:  adding tests to master
b7ee13e was Harvey Wu, 7 weeks ago, message: Merge pull request #19 from wuharvey/Kaitlin_edits_to_parser
bec83ba was Harvey Wu, 7 weeks ago, message: Merge branch 'master' into Kaitlin_edits_to_parser
7144505 was Harvey Wu, 7 weeks ago, message: Added FID to AST and added float stuff to codegen
fa776de was Harvey Wu, 7 weeks ago, message: Merge pull request #18 from wuharvey/cleanup
1f08473 was Harvey Wu, 7 weeks ago, message: Merge branch 'master' into cleanup
dcd2a25 was kpet123, 7 weeks ago, message: ADDED SET
69f015d was kpet123, 7 weeks ago, message: added set
1fb4aa7 was kpet123, 7 weeks ago, message: Update parser.mly
16d40fb was kpet123, 7 weeks ago, message: Update parser.mly
8e19bf5 was Kaitlin Pet, 7 weeks ago, message: about to push it
2af2b9a was Kaitlin Pet, 7 weeks ago, message: created enclosed_expression, which can go to id or stuff in parenthese
720079c was Kaitlin Pet, 7 weeks ago, message: moved assign to primaries and sub to expr
b6e8d1c was Kaitlin Pet, 7 weeks ago, message: made semi semi for sequening and connected funct_list explicitly to function declaration, also created actuals_list
5f9615c was Harvey Wu, 7 weeks ago, message: Fixed function call SR conflicts by adding a %prec
```

```
b52bbc5 was Harvey Wu, 7 weeks ago, message: Negating floats should not require a -. so deleted corresponding rule in parser.
8399c5b was Harvey Wu, 7 weeks ago, message: Added precedence for rhythmdot. Fixed other S/R conflicts - five left and an R/R.
4bf34ba was Harvey Wu, 7 weeks ago, message: added a primaries category per python and renamed FLiteral to FloatLit for consistency
9b446dc was Harvey Wu, 7 weeks ago, message: found source of most S/R conflicts and moved to complex expr section
d9d3def was Harvey Wu, 7 weeks ago, message: fixed some yacc errors. now to fix 127 sr conflicts
008ac56 was Harvey Wu, 7 weeks ago, message: Removed references to whitesp_list and rewrote formals/actuals stuff + other minor cleanup
30b8d67 was Husam Abdul-Kafi, 8 weeks ago, message: Ha codegen (#15)
3c01fde was kpet123, 8 weeks ago, message: Update parser.mly
79a043c was Harvey Wu, 8 weeks ago, message: added some defintions of types and fixed style issues for ast.ml
9a8a145 was Harvey Wu, 8 weeks ago, message: Readded formals_list. Fixed style issues. Fixed regexes for scanner.
816d99a was kpet123, 8 weeks ago, message: Update ast.ml
b66a557 was kpet123, 8 weeks ago, message: Update parser.mly
a3f3d07 was kpet123, 8 weeks ago, message: still needs for loop + concat
1780564 was kpet123, 8 weeks ago, message: Update ast.ml
85cd517 was kpet123, 8 weeks ago, message: Update parser.mly
a927f7a was kpet123, 8 weeks ago, message: most changes are commented in code
799cd1c was kpet123, 8 weeks ago, message: Update scanner.mll
c6a1be9 was Harvey Wu, 8 weeks ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
f4488c1 was Harvey Wu, 8 weeks ago, message: Removed most MicroC stuff from parser. Added proper fdecl.
59b108a was Harvey Wu, 8 weeks ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
b75cb5f was Harvey Wu, 8 weeks ago, message: Merge branch 'master' of https://github.com/wuharvey/music-mike
5863ba3 was Harvey Wu, 8 weeks ago, message: Added float operations to parser. Added new type FID (function ID) to
```

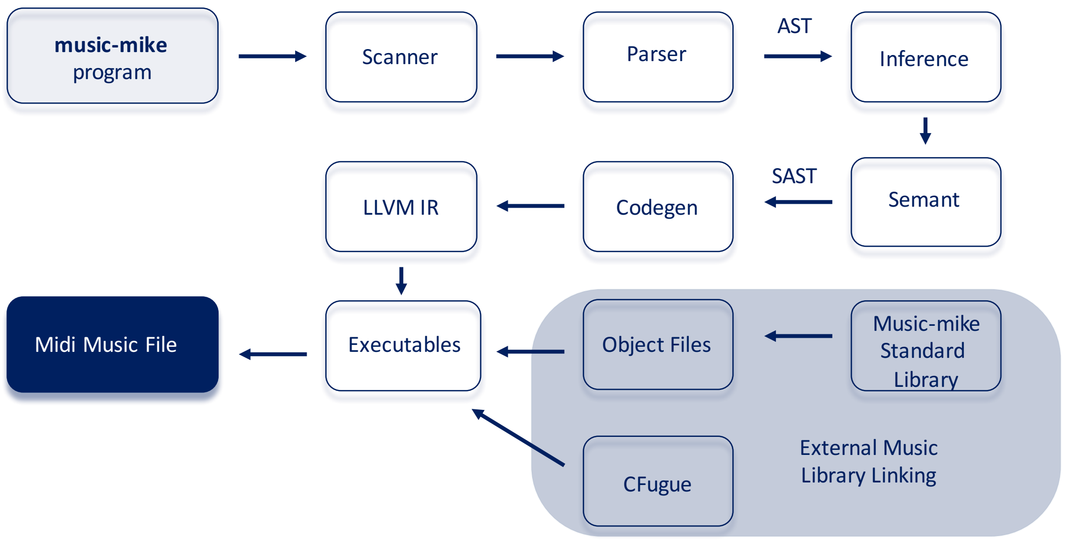
```
scanner for later convenience. Corrected regex for identifiers
to account for reserved single characters.
58136e4 was kpet123, 9 weeks ago, message: Update cfg.txt
ae697ee was kpet123, 9 weeks ago, message: Update cfg.txt
c8d4fce was kpet123, 9 weeks ago, message: Update cfg.txt
18a5016 was kpet123, 9 weeks ago, message: Update cfg.txt
45cc6cf was kpet123, 9 weeks ago, message: Update cfg.txt
7948745 was kpet123, 9 weeks ago, message: Update cfg.txt
5acae19 was kpet123, 9 weeks ago, message: Update cfg.txt
979e163 was kpet123, 9 weeks ago, message: Add files via
upload
c72ad97 was kpet123, 10 weeks ago, message: Update ast.ml
4e002d4 was habdulkafi, 10 weeks ago, message: added the
tokens to the token list in the parser and the associativity
(very wrong, but it's a start)
97bf924 was habdulkafi, 10 weeks ago, message: added microc
parser and ast
e728c44 was habdulkafi, 10 weeks ago, message: added brackets,
indexing, fops, pitchops, concat, and float literals to
scanner
11f1b6f was habdulkafi, 10 weeks ago, message: added microc
scanner
5f0b992 was Harvey Wu, 3 months ago, message: Update Project
Proposal.md
5fd2a6b was Harvey Wu, 8 weeks ago, message: Added float
operations to parser. Added new type FID (function ID) to
scanner for later convenience. Corrected regex for identifiers
to account for reserved single characters.
7be535e was kpet123, 9 weeks ago, message: Update cfg.txt
d44e2bb was kpet123, 9 weeks ago, message: Update cfg.txt
e6648b6 was kpet123, 9 weeks ago, message: Update cfg.txt
1361d6a was kpet123, 9 weeks ago, message: Update cfg.txt
ca233b9 was kpet123, 9 weeks ago, message: Update cfg.txt
21b7115 was kpet123, 9 weeks ago, message: Update cfg.txt
31eb6c8 was kpet123, 9 weeks ago, message: Update cfg.txt
5eb91d5 was kpet123, 9 weeks ago, message: Add files via
upload
b611496 was kpet123, 10 weeks ago, message: Update ast.ml
4cbc462 was habdulkafi, 10 weeks ago, message: added the
tokens to the token list in the parser and the associativity
(very wrong, but it's a start)
6845db8 was habdulkafi, 10 weeks ago, message: added microc
```

```
parser and ast
c0e9527 was habdulkafi, 10 weeks ago, message: added brackets, indexing, fops, pitchops, concat, and float literals to scanner
3d1705a was habdulkafi, 10 weeks ago, message: added microc scanner
0b9047f was Harvey Wu, 3 months ago, message: Update Project Proposal.md
b02d6bf was Harvey Wu, 3 months ago, message: Update Project Proposal.md
752894c was Harvey Wu, 3 months ago, message: Update Project Proposal.md
3ab535a was Harvey Wu, 3 months ago, message: Update Project Proposal.md
01d9e79 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
36d7140 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
a50edc7 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
d72ea47 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
0de79a0 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
7209a75 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
e0727d4 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
ef5b0b6 was Harvey Wu, 3 months ago, message: Update Project Proposal.md
072c5a1 was Harvey Wu, 3 months ago, message: Create README.md
2e89fe7 was Harvey Wu, 3 months ago, message: Project Proposal draft
```

5. Architectural Design

5.1 Block Diagram

Compiler Architecture



5.2 Interfaces

5.2.1 Scanner (Lakshmi, Husam, Harvey)

Relevant Files: scanner.mll

The scanner is written in Ocamllex and takes the .mike input to the compiler and tokenizes it into literals, identifiers, operators and keywords. It removes the white space and block comments. If any character cannot be lexed by the scanner or if any identifier or literal is not syntactically valid, the scanner throws an error. The tokens created by the scanner are used by the Parser to create an Abstract Syntax Tree. The scanner is context sensitive, so uses different pattern matching inside of rhythm and pitch lists.

5.2.2 Parser (Kaitlin, Husam, Harvey, Lakshmi)

Relevant Files: parser.mly

The parser is written in Ocamlyacc and takes in a series of tokens. It uses the grammar described in parser.mly and datatypes defined in ast.ml to generate an Abstract Syntax Tree. In parser.mly, we define the Music-mike context-free grammar using productions. If the tokens produced by the scanner are successfully parsed that means that the .mike file is syntactically (though perhaps not semantically) correct.

Certain operations are also directly translated to values in the parser. For example, the pitch prefield and postfield operators (Raise by 1 octave, Lower by 1 octave, Raise by half step, and lower by half step) were parsed directly into numerical values to be applied to the note value during the calling of the Synth function.

5.2.3 Type Inference (Harvey)

Relevant Files: infer.ml

The type inference module takes in the untyped AST of expressions and runs Algorithm W (Hindley Milner Type Inference). Type checking is also done in one swift pass - a list, for example, cannot contain elements of two different types. Scope is also handled in this module - a single global map stores variables and their types and thus typing is dynamic. Variables and functions cannot be redefined. Other semantic checking, such as argument counts

5.2.4 Semant (Lakshmi, Husam, Harvey)

Relevant Files: semant.ml

The semant module is an extension of type inference, and handles polymorphic functions. It first finds all the polymorphic functions, then finds all the calls made to these functions and adds in typed function definitions in place of the dummy type polymorphic functions.

5.2.5 The Code Generator (Husam, Kaitlin, Lakshmi)

Relevant Files: codegen.ml

Our Codegen was similar to that of MicroC with the exception of a few key features. First of all, everything is an expression and evaluates to either a value or void. This structure made it easy for us to nest expressions within one another and take advantage of OCaml's pattern-matching abilities.

Especially notable was our plethora of structures to manipulate lists. To keeps track of lengths of lists, all lists are not pure pointers but consist of a struct where the first field is length and the second field is a pointer to the list itself. Because the second field contains a pointer, it is sufficient for all single-layer lists.

For multi-layer lists such as the Chordlist structure, this struct was repeated across multiple layers. The data structure consists of a chordlist consisting of chords where each chord consists of pitches and each pitch consists of a 3-tuple. In this case, length information was necessary for chordlist and chord, so those structures were the structs as described above. Since length information was not important for pitches (malloced every time at a set length of 3), pointers to pitches were just int *.

6. Test Plan

6.1 Example tests

05/10/17 11:47:33 C:\Users\husam\Downloads\bach.mike

```
minor1 = [11 13 14 16 18 20 22 23 9];
minor2 = [11 13 14 16 18 20 22 23 10];
theme = p:[0 1 3 5 8 7 8 7b 8 6 8 6b 8 5 8 7 8 4# 6 3 2 3 4# 2
1 v7b 5];
r1 = r:[0. .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1
.1 .1 .1 .1 .1 .1 .1 .2 .2];
r2 = r:[2.5 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1
.1 .1 .1 .1 .1 .1 .1 .2 .2];

counter = p:[0 5 6 5 4 3 2 4 3 2 1 v7 1 2 v7 1];
r3 = r:[.1 .1 .1 .1 .1 .1 .1 .1 .5 .1 .1 .1 .1 .1 .1 .1];
arp = p:[0 v5 v7 2 4 v7 2 4 6 5 4 6 5 4 3 2 1 v7 v6 v5 3];
r4 = r:[s s s s s s s s s s s s s s s s s s s s 1.25];

rone = Synth(theme r1 minor1 50 1);
rtwo = Synth(counter r3 minor1 (50 + 7) 1);
lone = Synth(theme r2 minor1 33 2);

song = Merge(rone lone);
song1 = Merge(song rtwo);
Make_midi(song1 "bach.midi");
```

```

duleID = 'MusicMike'

%list_struct = type <{ i32, i32* }>
%chordlist_struct = type <{ i32, %chord_struct* }>
%chord_struct = type <{ i32, i32** }>
%list_struct_f = type <{ i32, double* }>

@fmt = private unnamed_addr constant [4 x i8] c"%d\0A\00"
@str = private unnamed_addr constant [4 x i8] c"%s\0A\00"
@flt = private unnamed_addr constant [4 x i8] c"%f\0A\00"
@str.1 = private unnamed_addr constant [3 x i8] c"%c\00"
@fmt.2 = private unnamed_addr constant [4 x i8] c"%d \00"
@fmt.3 = private unnamed_addr constant [4 x i8] c"%f \00"
@0 = private unnamed_addr constant [10 x i8] c"bach.midi\00"

declare i32 @printf(i8*, ...)

define i32 @main() {
entry:
  %array_struct = alloca %list_struct
  %length = getelementptr inbounds %list_struct,
%list_struct* %array_struct, i32 0, i32 0
  store i32 9, i32* %length
  %array = alloca i32, i32 9
  %elem = getelementptr i32, i32* %array, i32 0
  store i32 11, i32* %elem
  %elem1 = getelementptr i32, i32* %array, i32 1
  store i32 13, i32* %elem1
  %elem2 = getelementptr i32, i32* %array, i32 2
  store i32 14, i32* %elem2
  %elem3 = getelementptr i32, i32* %array, i32 3
  store i32 16, i32* %elem3
  %elem4 = getelementptr i32, i32* %array, i32 4
  store i32 18, i32* %elem4
  %elem5 = getelementptr i32, i32* %array, i32 5
  store i32 20, i32* %elem5
  %elem6 = getelementptr i32, i32* %array, i32 6
  store i32 22, i32* %elem6
  %elem7 = getelementptr i32, i32* %array, i32 7
  store i32 23, i32* %elem7
  %elem8 = getelementptr i32, i32* %array, i32 8
  store i32 9, i32* %elem8
  %actual_list = getelementptr inbounds %list_struct,
%list_struct* %array_struct, i32 0, i32 1
  store i32* %array, i32** %actual_list
  %minor1 = alloca %list_struct*
  store %list_struct* %array_struct, %list_struct** %minor1
  %array_struct9 = alloca %list_struct
  %length10 = getelementptr inbounds %list_struct,
%list_struct* %array_struct9, i32 0, i32 0
  store i32 9, i32* %length10
  %array11 = alloca i32, i32 9
  %elem12 = getelementptr i32, i32* %array11, i32 0
  store i32 11, i32* %elem12
  %elem13 = getelementptr i32, i32* %array11, i32 1
  store i32 13, i32* %elem13
  %elem14 = getelementptr i32, i32* %array11, i32 2
  store i32 14, i32* %elem14
  %elem15 = getelementptr i32, i32* %array11, i32 3
  store i32 16, i32* %elem15
  %elem16 = getelementptr i32, i32* %array11, i32 4
  store i32 18, i32* %elem16
  %elem17 = getelementptr i32, i32* %array11, i32 5
  store i32 20, i32* %elem17
  %elem18 = getelementptr i32, i32* %array11, i32 6
  store i32 22, i32* %elem18
  %elem19 = getelementptr i32, i32* %array11, i32 7
  store i32 23, i32* %elem19
  %elem20 = getelementptr i32, i32* %array11, i32 8
  store i32 10, i32* %elem20
  %actual_list21 = getelementptr inbounds %list_struct,
%list_struct* %array_struct9, i32 0, i32 1
  store i32* %array11, i32** %actual_list21
  %minor2 = alloca %list_struct*
  store %list_struct* %array_struct9, %list_struct** %minor2
  %malloccall = tail call i8* @malloc(i32 ptrtoint
(%chordlist_struct* getelementptr (%chordlist_struct,
%chordlist_struct* null, i32 1) to i32))
  %cl_struct = bitcast i8* %malloccall to %chordlist_struct*
  %length22 = getelementptr inbounds %chordlist_struct,
%chordlist_struct* %cl_struct, i32 0, i32 0
```

```
  store i32 27, i32* %length22
  %malloccall23 = tail call i8* @malloc(i32 mul (i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32), i32 27))
  %chord_pointer_array = bitcast i8* %malloccall23 to
%chord_struct*
  %pointer_chord_elem_list = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 0
  %malloccall24 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct = bitcast i8* %malloccall24 to %chord_struct*
  %length25 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct, i32 0, i32 0
  store i32 1, i32* %length25
  %malloccall26 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch = bitcast i8* %malloccall26 to i32**
  %pitch_pointer_elem = getelementptr i32*, i32** %arr_pitch,
i32 0
  %malloccall27 = tail call i8* @malloc(i32 mul (i32 ptrtoint
(i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array28 = bitcast i8* %malloccall27 to i32*
  %prefield_elem = getelementptr i32, i32* %array28, i32 0
  store i32 0, i32* %prefield_elem
  %scaledegreer_elem = getelementptr i32, i32* %array28, i32
1
  store i32 0, i32* %scaledegreer_elem
  %postfield_elem = getelementptr i32, i32* %array28, i32 2
  store i32 0, i32* %postfield_elem
  store i32* %array28, i32** %pitch_pointer_elem
  %struct_c_pointer = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct, i32 0, i32 1
  store i32** %arr_pitch, i32*** %struct_c_pointer
  %actual_chord_struct = load %chord_struct, %chord_struct*
%chord_struct
  store %chord_struct %actual_chord_struct, %chord_struct*
%pointer_chord_elem_list
  %pointer_chord_elem_list29 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 1
  %malloccall30 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct31 = bitcast i8* %malloccall30 to %chord_struct*
  %length32 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct31, i32 0, i32 0
  store i32 1, i32* %length32
  %malloccall33 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch34 = bitcast i8* %malloccall33 to i32**
  %pitch_pointer_elem35 = getelementptr i32*, i32** %arr_pitch34, i32 0
  %malloccall36 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array37 = bitcast i8* %malloccall36 to i32*
  %prefield_elem38 = getelementptr i32, i32* %array37, i32 0
  store i32 0, i32* %prefield_elem38
  %scaledegreer_elem39 = getelementptr i32, i32* %array37, i32 1
  store i32 1, i32* %scaledegreer_elem39
  %postfield_elem40 = getelementptr i32, i32* %array37, i32 2
  store i32 0, i32* %postfield_elem40
  store i32* %array37, i32** %pitch_pointer_elem35
  %struct_c_pointer41 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct31, i32 0, i32 1
  store i32** %arr_pitch34, i32*** %struct_c_pointer41
  %actual_chord_struct42 = load %chord_struct, %chord_struct* %chord_struct31
  store %chord_struct %actual_chord_struct42, %chord_struct* %pointer_chord_elem_list29
  %pointer_chord_elem_list43 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 2
  %malloccall44 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct45 = bitcast i8* %malloccall44 to %chord_struct*
  %length46 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct45, i32 0, i32 0
  store i32 1, i32* %length46
  %malloccall47 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch48 = bitcast i8* %malloccall47 to i32**
  %pitch_pointer_elem49 = getelementptr i32*, i32** %arr_pitch48, i32 0
  %malloccall50 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array51 = bitcast i8* %malloccall50 to i32*
  %prefield_elem52 = getelementptr i32, i32* %array51, i32 0
  store i32 0, i32* %prefield_elem52
  %scaledegreer_elem53 = getelementptr i32, i32* %array51, i32 1
  store i32 3, i32* %scaledegreer_elem53
  %postfield_elem54 = getelementptr i32, i32* %array51, i32 2
  store i32 0, i32* %postfield_elem54
  store i32* %array51, i32** %pitch_pointer_elem49
  %struct_c_pointer55 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct45, i32 0, i32 1
  store i32** %arr_pitch48, i32*** %struct_c_pointer55
  %actual_chord_struct56 = load %chord_struct, %chord_struct* %chord_struct45
  store %chord_struct %actual_chord_struct56, %chord_struct* %pointer_chord_elem_list43
  %pointer_chord_elem_list57 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 3
  %malloccall58 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct59 = bitcast i8* %malloccall58 to %chord_struct*
  %length60 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct59, i32 0, i32 0
  store i32 1, i32* %length60
  %malloccall61 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch62 = bitcast i8* %malloccall61 to i32**
  %pitch_pointer_elem63 = getelementptr i32*, i32** %arr_pitch62, i32 0
  %malloccall64 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array65 = bitcast i8* %malloccall64 to i32*
  %prefield_elem66 = getelementptr i32, i32* %array65, i32 0
  store i32 0, i32* %prefield_elem66
  %scaledegreer_elem67 = getelementptr i32, i32* %array65, i32 1
  store i32 5, i32* %scaledegreer_elem67
  %postfield_elem68 = getelementptr i32, i32* %array65, i32 2
  store i32 0, i32* %postfield_elem68
  store i32* %array65, i32** %pitch_pointer_elem63
  %struct_c_pointer69 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct59, i32 0, i32 1
  store i32** %arr_pitch62, i32*** %struct_c_pointer69
  %actual_chord_struct70 = load %chord_struct, %chord_struct*
%chord_struct59
  store %chord_struct %actual_chord_struct70, %chord_struct*
%pointer_chord_elem_list57
  %pointer_chord_elem_list71 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 4
  %malloccall72 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct73 = bitcast i8* %malloccall72 to
%chord_struct*
  %length74 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct73, i32 0, i32 0
  store i32 1, i32* %length74
  %malloccall75 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch76 = bitcast i8* %malloccall75 to i32**
  %pitch_pointer_elem77 = getelementptr i32*, i32**
%arr_pitch76, i32 0
  %malloccall78 = tail call i8* @malloc(i32 mul (i32 ptrtoint
(i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array79 = bitcast i8* %malloccall78 to i32*
  %prefield_elem80 = getelementptr i32, i32* %array79, i32 0
  store i32 0, i32* %prefield_elem80
  %scaledegreer_elem81 = getelementptr i32, i32* %array79,
i32 1
  store i32 8, i32* %scaledegreer_elem81
  %postfield_elem82 = getelementptr i32, i32* %array79, i32 2
  store i32 0, i32* %postfield_elem82
  store i32* %array79, i32** %pitch_pointer_elem77
  %struct_c_pointer83 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct73, i32 0, i32 1
  store i32** %arr_pitch76, i32*** %struct_c_pointer83
  %actual_chord_struct84 = load %chord_struct, %chord_struct*
%chord_struct73
```

```
  store %chord_struct %actual_chord_struct84, %chord_struct*
%pointer_chord_elem_list71
  %pointer_chord_elem_list85 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 5
  %malloccall86 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct87 = bitcast i8* %malloccall86 to
%chord_struct*
  %length88 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct87, i32 0, i32 0
  store i32 1, i32* %length88
  %malloccall89 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch90 = bitcast i8* %malloccall89 to i32**
  %pitch_pointer_elem91 = getelementptr i32*, i32**
%arr_pitch90, i32 0
  %malloccall92 = tail call i8* @malloc(i32 mul (i32 ptrtoint
(i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array93 = bitcast i8* %malloccall92 to i32*
  %prefield_elem94 = getelementptr i32, i32* %array93, i32 0
  store i32 0, i32* %prefield_elem94
  %scaledegreer_elem95 = getelementptr i32, i32* %array93,
i32 1
  store i32 7, i32* %scaledegreer_elem95
  %postfield_elem96 = getelementptr i32, i32* %array93, i32 2
  store i32 0, i32* %postfield_elem96
  store i32* %array93, i32** %pitch_pointer_elem91
  %struct_c_pointer97 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct87, i32 0, i32 1
  store i32** %arr_pitch90, i32*** %struct_c_pointer97
  %actual_chord_struct98 = load %chord_struct, %chord_struct*
%chord_struct87
  store %chord_struct %actual_chord_struct98, %chord_struct*
%pointer_chord_elem_list85
  %pointer_chord_elem_list99 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 6
  %malloccall100 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct101 = bitcast i8* %malloccall100 to
%chord_struct*
```

```
  %length102 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct101, i32 0, i32 0
  store i32 1, i32* %length102
  %malloccall103 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch104 = bitcast i8* %malloccall103 to i32**
  %pitch_pointer_elem105 = getelementptr i32*, i32** %arr_pitch104, i32 0
  %malloccall106 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array107 = bitcast i8* %malloccall106 to i32*
  %prefield_elem108 = getelementptr i32, i32* %array107, i32 0
  store i32 0, i32* %prefield_elem108
  %scaledegreer_elem109 = getelementptr i32, i32* %array107, i32 1
  store i32 8, i32* %scaledegreer_elem109
  %postfield_elem110 = getelementptr i32, i32* %array107, i32 2
  store i32 0, i32* %postfield_elem110
  store i32* %array107, i32** %pitch_pointer_elem105
  %struct_c_pointer111 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct101, i32 0, i32 1
  store i32** %arr_pitch104, i32*** %struct_c_pointer111
  %actual_chord_struct112 = load %chord_struct, %chord_struct* %chord_struct101
  store %chord_struct %actual_chord_struct112, %chord_struct* %pointer_chord_elem_list99
  %pointer_chord_elem_list113 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 7
  %malloccall114 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct115 = bitcast i8* %malloccall114 to %chord_struct*
  %length116 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct115, i32 0, i32 0
  store i32 1, i32* %length116
  %malloccall117 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch118 = bitcast i8* %malloccall117 to i32**
  %pitch_pointer_elem119 = getelementptr i32*, i32** %arr_pitch118, i32 0
  %malloccall120 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array121 = bitcast i8* %malloccall120 to i32*
  %prefield_elem122 = getelementptr i32, i32* %array121, i32 0
  store i32 0, i32* %prefield_elem122
  %scaledegreer_elem123 = getelementptr i32, i32* %array121, i32 1
  store i32 7, i32* %scaledegreer_elem123
  %postfield_elem124 = getelementptr i32, i32* %array121, i32 2
  store i32 -1, i32* %postfield_elem124
  store i32* %array121, i32** %pitch_pointer_elem119
  %struct_c_pointer125 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct115, i32 0, i32 1
  store i32** %arr_pitch118, i32*** %struct_c_pointer125
  %actual_chord_struct126 = load %chord_struct, %chord_struct* %chord_struct115
  store %chord_struct %actual_chord_struct126, %chord_struct* %pointer_chord_elem_list113
  %pointer_chord_elem_list127 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 8
  %malloccall128 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct129 = bitcast i8* %malloccall128 to %chord_struct*
  %length130 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct129, i32 0, i32 0
  store i32 1, i32* %length130
  %malloccall131 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch132 = bitcast i8* %malloccall131 to i32**
  %pitch_pointer_elem133 = getelementptr i32*, i32** %arr_pitch132, i32 0
  %malloccall134 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array135 = bitcast i8* %malloccall134 to i32*
  %prefield_elem136 = getelementptr i32, i32* %array135, i32
0
  store i32 0, i32* %prefield_elem136
  %scaledegreer_elem137 = getelementptr i32, i32* %array135,
i32 1
  store i32 8, i32* %scaledegreer_elem137
  %postfield_elem138 = getelementptr i32, i32* %array135, i32
2
  store i32 0, i32* %postfield_elem138
  store i32* %array135, i32** %pitch_pointer_elem133
  %struct_c_pointer139 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct129, i32 0, i32 1
  store i32** %arr_pitch132, i32*** %struct_c_pointer139
  %actual_chord_struct140 = load %chord_struct,
%chord_struct* %chord_struct129
  store %chord_struct %actual_chord_struct140, %chord_struct*
%pointer_chord_elem_list127
  %pointer_chord_elem_list141 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 9
  %malloccall142 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct143 = bitcast i8* %malloccall142 to
%chord_struct*
  %length144 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct143, i32 0, i32 0
  store i32 1, i32* %length144
  %malloccall145 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch146 = bitcast i8* %malloccall145 to i32**
  %pitch_pointer_elem147 = getelementptr i32*, i32**
%arr_pitch146, i32 0
  %malloccall148 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array149 = bitcast i8* %malloccall148 to i32*
  %prefield_elem150 = getelementptr i32, i32* %array149, i32
0
  store i32 0, i32* %prefield_elem150
  %scaledegreer_elem151 = getelementptr i32, i32* %array149,
i32 1
  store i32 6, i32* %scaledegreer_elem151
  %postfield_elem152 = getelementptr i32, i32* %array149, i32
2
  store i32 0, i32* %postfield_elem152
  store i32* %array149, i32** %pitch_pointer_elem147
  %struct_c_pointer153 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct143, i32 0, i32 1
  store i32** %arr_pitch146, i32*** %struct_c_pointer153
  %actual_chord_struct154 = load %chord_struct,
%chord_struct* %chord_struct143
  store %chord_struct %actual_chord_struct154, %chord_struct*
%pointer_chord_elem_list141
  %pointer_chord_elem_list155 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 10
  %malloccall156 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct157 = bitcast i8* %malloccall156 to
%chord_struct*
  %length158 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct157, i32 0, i32 0
  store i32 1, i32* %length158
  %malloccall159 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch160 = bitcast i8* %malloccall159 to i32**
  %pitch_pointer_elem161 = getelementptr i32*, i32**
%arr_pitch160, i32 0
  %malloccall162 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array163 = bitcast i8* %malloccall162 to i32*
  %prefield_elem164 = getelementptr i32, i32* %array163, i32
0
  store i32 0, i32* %prefield_elem164
  %scaledegreer_elem165 = getelementptr i32, i32* %array163,
i32 1
  store i32 8, i32* %scaledegreer_elem165
  %postfield_elem166 = getelementptr i32, i32* %array163, i32
2
  store i32 0, i32* %postfield_elem166
  store i32* %array163, i32** %pitch_pointer_elem161
  %struct_c_pointer167 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct157, i32 0, i32 1
```

```
  store i32** %arr_pitch160, i32*** %struct_c_pointer167
  %actual_chord_struct168 = load %chord_struct,
%chord_struct* %chord_struct157
  store %chord_struct %actual_chord_struct168, %chord_struct*
%pointer_chord_elem_list155
  %pointer_chord_elem_list169 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 11
  %malloccall170 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct171 = bitcast i8* %malloccall170 to
%chord_struct*
  %length172 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct171, i32 0, i32 0
  store i32 1, i32* %length172
  %malloccall173 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch174 = bitcast i8* %malloccall173 to i32**
  %pitch_pointer_elem175 = getelementptr i32*, i32**
%arr_pitch174, i32 0
  %malloccall176 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array177 = bitcast i8* %malloccall176 to i32*
  %prefield_elem178 = getelementptr i32, i32* %array177, i32
0
  store i32 0, i32* %prefield_elem178
  %scaledegreer_elem179 = getelementptr i32, i32* %array177,
i32 1
  store i32 6, i32* %scaledegreer_elem179
  %postfield_elem180 = getelementptr i32, i32* %array177, i32
2
  store i32 -1, i32* %postfield_elem180
  store i32* %array177, i32** %pitch_pointer_elem175
  %struct_c_pointer181 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct171, i32 0, i32 1
  store i32** %arr_pitch174, i32*** %struct_c_pointer181
  %actual_chord_struct182 = load %chord_struct,
%chord_struct* %chord_struct171
  store %chord_struct %actual_chord_struct182, %chord_struct*
%pointer_chord_elem_list169
  %pointer_chord_elem_list183 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 12
  %malloccall184 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct185 = bitcast i8* %malloccall184 to %chord_struct*
  %length186 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct185, i32 0, i32 0
  store i32 1, i32* %length186
  %malloccall187 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch188 = bitcast i8* %malloccall187 to i32**
  %pitch_pointer_elem189 = getelementptr i32*, i32** %arr_pitch188, i32 0
  %malloccall190 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array191 = bitcast i8* %malloccall190 to i32*
  %prefield_elem192 = getelementptr i32, i32* %array191, i32 0
  store i32 0, i32* %prefield_elem192
  %scaledegreer_elem193 = getelementptr i32, i32* %array191, i32 1
  store i32 8, i32* %scaledegreer_elem193
  %postfield_elem194 = getelementptr i32, i32* %array191, i32 2
  store i32 0, i32* %postfield_elem194
  store i32* %array191, i32** %pitch_pointer_elem189
  %struct_c_pointer195 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct185, i32 0, i32 1
  store i32** %arr_pitch188, i32*** %struct_c_pointer195
  %actual_chord_struct196 = load %chord_struct, %chord_struct* %chord_struct185
  store %chord_struct %actual_chord_struct196, %chord_struct* %pointer_chord_elem_list183
  %pointer_chord_elem_list197 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 13
  %malloccall198 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct199 = bitcast i8* %malloccall198 to %chord_struct*
  %length200 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct199, i32 0, i32 0
  store i32 1, i32* %length200
  %malloccall201 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch202 = bitcast i8* %malloccall201 to i32**
  %pitch_pointer_elem203 = getelementptr i32*, i32**
%arr_pitch202, i32 0
  %malloccall204 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array205 = bitcast i8* %malloccall204 to i32*
  %prefield_elem206 = getelementptr i32, i32* %array205, i32
0
  store i32 0, i32* %prefield_elem206
  %scaledegreer_elem207 = getelementptr i32, i32* %array205,
i32 1
  store i32 5, i32* %scaledegreer_elem207
  %postfield_elem208 = getelementptr i32, i32* %array205, i32
2
  store i32 0, i32* %postfield_elem208
  store i32* %array205, i32** %pitch_pointer_elem203
  %struct_c_pointer209 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct199, i32 0, i32 1
  store i32** %arr_pitch202, i32*** %struct_c_pointer209
  %actual_chord_struct210 = load %chord_struct,
%chord_struct* %chord_struct199
  store %chord_struct %actual_chord_struct210, %chord_struct*
%pointer_chord_elem_list197
  %pointer_chord_elem_list211 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 14
  %malloccall212 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct213 = bitcast i8* %malloccall212 to
%chord_struct*
  %length214 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct213, i32 0, i32 0
  store i32 1, i32* %length214
  %malloccall215 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch216 = bitcast i8* %malloccall215 to i32**
  %pitch_pointer_elem217 = getelementptr i32*, i32**
%arr_pitch216, i32 0
  %malloccall218 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array219 = bitcast i8* %malloccall218 to i32*
  %prefield_elem220 = getelementptr i32, i32* %array219, i32
0
  store i32 0, i32* %prefield_elem220
  %scaledegreer_elem221 = getelementptr i32, i32* %array219,
i32 1
  store i32 8, i32* %scaledegreer_elem221
  %postfield_elem222 = getelementptr i32, i32* %array219, i32
2
  store i32 0, i32* %postfield_elem222
  store i32* %array219, i32** %pitch_pointer_elem217
  %struct_c_pointer223 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct213, i32 0, i32 1
  store i32** %arr_pitch216, i32*** %struct_c_pointer223
  %actual_chord_struct224 = load %chord_struct,
%chord_struct* %chord_struct213
  store %chord_struct %actual_chord_struct224, %chord_struct*
%pointer_chord_elem_list211
  %pointer_chord_elem_list225 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 15
  %malloccall226 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct227 = bitcast i8* %malloccall226 to
%chord_struct*
  %length228 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct227, i32 0, i32 0
  store i32 1, i32* %length228
  %malloccall229 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch230 = bitcast i8* %malloccall229 to i32**
  %pitch_pointer_elem231 = getelementptr i32*, i32**
%arr_pitch230, i32 0
  %malloccall232 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array233 = bitcast i8* %malloccall232 to i32*
  %prefield_elem234 = getelementptr i32, i32* %array233, i32 0
  store i32 0, i32* %prefield_elem234
  %scaledegreer_elem235 = getelementptr i32, i32* %array233, i32 1
  store i32 7, i32* %scaledegreer_elem235
  %postfield_elem236 = getelementptr i32, i32* %array233, i32 2
  store i32 0, i32* %postfield_elem236
  store i32* %array233, i32** %pitch_pointer_elem231
  %struct_c_pointer237 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct227, i32 0, i32 1
  store i32** %arr_pitch230, i32*** %struct_c_pointer237
  %actual_chord_struct238 = load %chord_struct, %chord_struct* %chord_struct227
  store %chord_struct %actual_chord_struct238, %chord_struct* %pointer_chord_elem_list225
  %pointer_chord_elem_list239 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 16
  %malloccall240 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct241 = bitcast i8* %malloccall240 to %chord_struct*
  %length242 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct241, i32 0, i32 0
  store i32 1, i32* %length242
  %malloccall243 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch244 = bitcast i8* %malloccall243 to i32**
  %pitch_pointer_elem245 = getelementptr i32*, i32** %arr_pitch244, i32 0
  %malloccall246 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array247 = bitcast i8* %malloccall246 to i32*
  %prefield_elem248 = getelementptr i32, i32* %array247, i32 0
  store i32 0, i32* %prefield_elem248
  %scaledegreer_elem249 = getelementptr i32, i32* %array247, i32 1
  store i32 8, i32* %scaledegreer_elem249
  %postfield_elem250 = getelementptr i32, i32* %array247, i32
2
  store i32 0, i32* %postfield_elem250
  store i32* %array247, i32** %pitch_pointer_elem245
  %struct_c_pointer251 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct241, i32 0, i32 1
  store i32** %arr_pitch244, i32*** %struct_c_pointer251
  %actual_chord_struct252 = load %chord_struct,
%chord_struct* %chord_struct241
  store %chord_struct %actual_chord_struct252, %chord_struct*
%pointer_chord_elem_list239
  %pointer_chord_elem_list253 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 17
  %malloccall254 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct255 = bitcast i8* %malloccall254 to
%chord_struct*
  %length256 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct255, i32 0, i32 0
  store i32 1, i32* %length256
  %malloccall257 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch258 = bitcast i8* %malloccall257 to i32**
  %pitch_pointer_elem259 = getelementptr i32*, i32**
%arr_pitch258, i32 0
  %malloccall260 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array261 = bitcast i8* %malloccall260 to i32*
  %prefield_elem262 = getelementptr i32, i32* %array261, i32
0
  store i32 0, i32* %prefield_elem262
  %scaledegreer_elem263 = getelementptr i32, i32* %array261,
i32 1
  store i32 4, i32* %scaledegreer_elem263
  %postfield_elem264 = getelementptr i32, i32* %array261, i32
2
  store i32 1, i32* %postfield_elem264
  store i32* %array261, i32** %pitch_pointer_elem259
  %struct_c_pointer265 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct255, i32 0, i32 1
```

```
  store i32** %arr_pitch258, i32*** %struct_c_pointer265
  %actual_chord_struct266 = load %chord_struct, %chord_struct* %chord_struct255
  store %chord_struct %actual_chord_struct266, %chord_struct* %pointer_chord_elem_list253
  %pointer_chord_elem_list267 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 18
  %malloccall268 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct269 = bitcast i8* %malloccall268 to %chord_struct*
  %length270 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct269, i32 0, i32 0
  store i32 1, i32* %length270
  %malloccall271 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch272 = bitcast i8* %malloccall271 to i32**
  %pitch_pointer_elem273 = getelementptr i32*, i32** %arr_pitch272, i32 0
  %malloccall274 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array275 = bitcast i8* %malloccall274 to i32*
  %prefield_elem276 = getelementptr i32, i32* %array275, i32 0
  store i32 0, i32* %prefield_elem276
  %scaledegreer_elem277 = getelementptr i32, i32* %array275, i32 1
  store i32 6, i32* %scaledegreer_elem277
  %postfield_elem278 = getelementptr i32, i32* %array275, i32 2
  store i32 0, i32* %postfield_elem278
  store i32* %array275, i32** %pitch_pointer_elem273
  %struct_c_pointer279 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct269, i32 0, i32 1
  store i32** %arr_pitch272, i32*** %struct_c_pointer279
  %actual_chord_struct280 = load %chord_struct, %chord_struct* %chord_struct269
  store %chord_struct %actual_chord_struct280, %chord_struct* %pointer_chord_elem_list267
  %pointer_chord_elem_list281 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 19
  %malloccall282 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct283 = bitcast i8* %malloccall282 to %chord_struct*
  %length284 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct283, i32 0, i32 0
  store i32 1, i32* %length284
  %malloccall285 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch286 = bitcast i8* %malloccall285 to i32**
  %pitch_pointer_elem287 = getelementptr i32*, i32** %arr_pitch286, i32 0
  %malloccall288 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array289 = bitcast i8* %malloccall288 to i32*
  %prefield_elem290 = getelementptr i32, i32* %array289, i32 0
  store i32 0, i32* %prefield_elem290
  %scaledegreer_elem291 = getelementptr i32, i32* %array289, i32 1
  store i32 3, i32* %scaledegreer_elem291
  %postfield_elem292 = getelementptr i32, i32* %array289, i32 2
  store i32 0, i32* %postfield_elem292
  store i32* %array289, i32** %pitch_pointer_elem287
  %struct_c_pointer293 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct283, i32 0, i32 1
  store i32** %arr_pitch286, i32*** %struct_c_pointer293
  %actual_chord_struct294 = load %chord_struct, %chord_struct* %chord_struct283
  store %chord_struct %actual_chord_struct294, %chord_struct* %pointer_chord_elem_list281
  %pointer_chord_elem_list295 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 20
  %malloccall296 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct297 = bitcast i8* %malloccall296 to %chord_struct*
  %length298 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct297, i32 0, i32 0
  store i32 1, i32* %length298
  %malloccall299 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch300 = bitcast i8* %malloccall299 to i32**
  %pitch_pointer_elem301 = getelementptr i32*, i32** %arr_pitch300, i32 0
  %malloccall302 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array303 = bitcast i8* %malloccall302 to i32*
  %prefield_elem304 = getelementptr i32, i32* %array303, i32 0
  store i32 0, i32* %prefield_elem304
  %scaledegreer_elem305 = getelementptr i32, i32* %array303, i32 1
  store i32 2, i32* %scaledegreer_elem305
  %postfield_elem306 = getelementptr i32, i32* %array303, i32 2
  store i32 0, i32* %postfield_elem306
  store i32* %array303, i32** %pitch_pointer_elem301
  %struct_c_pointer307 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct297, i32 0, i32 1
  store i32** %arr_pitch300, i32*** %struct_c_pointer307
  %actual_chord_struct308 = load %chord_struct, %chord_struct* %chord_struct297
  store %chord_struct %actual_chord_struct308, %chord_struct* %pointer_chord_elem_list295
  %pointer_chord_elem_list309 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 21
  %malloccall310 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct311 = bitcast i8* %malloccall310 to %chord_struct*
  %length312 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct311, i32 0, i32 0
  store i32 1, i32* %length312
  %malloccall313 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch314 = bitcast i8* %malloccall313 to i32**
  %pitch_pointer_elem315 = getelementptr i32*, i32** %arr_pitch314, i32 0
  %malloccall316 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array317 = bitcast i8* %malloccall316 to i32*
  %prefield_elem318 = getelementptr i32, i32* %array317, i32 0
  store i32 0, i32* %prefield_elem318
  %scaledegreer_elem319 = getelementptr i32, i32* %array317, i32 1
  store i32 3, i32* %scaledegreer_elem319
  %postfield_elem320 = getelementptr i32, i32* %array317, i32 2
  store i32 0, i32* %postfield_elem320
  store i32* %array317, i32** %pitch_pointer_elem315
  %struct_c_pointer321 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct311, i32 0, i32 1
  store i32** %arr_pitch314, i32*** %struct_c_pointer321
  %actual_chord_struct322 = load %chord_struct, %chord_struct* %chord_struct311
  store %chord_struct %actual_chord_struct322, %chord_struct* %pointer_chord_elem_list309
  %pointer_chord_elem_list323 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 22
  %malloccall324 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct325 = bitcast i8* %malloccall324 to %chord_struct*
  %length326 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct325, i32 0, i32 0
  store i32 1, i32* %length326
  %malloccall327 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch328 = bitcast i8* %malloccall327 to i32**
  %pitch_pointer_elem329 = getelementptr i32*, i32** %arr_pitch328, i32 0
  %malloccall330 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array331 = bitcast i8* %malloccall330 to i32*
  %prefield_elem332 = getelementptr i32, i32* %array331, i32 0
  store i32 0, i32* %prefield_elem332
  %scaledegreer_elem333 = getelementptr i32, i32* %array331, i32 1
  store i32 4, i32* %scaledegreer_elem333
  %postfield_elem334 = getelementptr i32, i32* %array331, i32 2
  store i32 1, i32* %postfield_elem334
  store i32* %array331, i32** %pitch_pointer_elem329
  %struct_c_pointer335 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct325, i32 0, i32 1
  store i32** %arr_pitch328, i32*** %struct_c_pointer335
  %actual_chord_struct336 = load %chord_struct, %chord_struct* %chord_struct325
  store %chord_struct %actual_chord_struct336, %chord_struct* %pointer_chord_elem_list323
  %pointer_chord_elem_list337 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 23
  %malloccall338 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct339 = bitcast i8* %malloccall338 to %chord_struct*
  %length340 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct339, i32 0, i32 0
  store i32 1, i32* %length340
  %malloccall341 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch342 = bitcast i8* %malloccall341 to i32**
  %pitch_pointer_elem343 = getelementptr i32*, i32** %arr_pitch342, i32 0
  %malloccall344 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array345 = bitcast i8* %malloccall344 to i32*
  %prefield_elem346 = getelementptr i32, i32* %array345, i32 0
  store i32 0, i32* %prefield_elem346
  %scaledegreer_elem347 = getelementptr i32, i32* %array345, i32 1
  store i32 2, i32* %scaledegreer_elem347
  %postfield_elem348 = getelementptr i32, i32* %array345, i32 2
  store i32 0, i32* %postfield_elem348
  store i32* %array345, i32** %pitch_pointer_elem343
  %struct_c_pointer349 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct339, i32 0, i32 1
  store i32** %arr_pitch342, i32*** %struct_c_pointer349
  %actual_chord_struct350 = load %chord_struct, %chord_struct* %chord_struct339
  store %chord_struct %actual_chord_struct350, %chord_struct* %pointer_chord_elem_list337
  %pointer_chord_elem_list351 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array, i32 24
  %malloccall352 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct353 = bitcast i8* %malloccall352 to %chord_struct*
  %length354 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct353, i32 0, i32 0
  store i32 1, i32* %length354
  %malloccall355 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch356 = bitcast i8* %malloccall355 to i32**
  %pitch_pointer_elem357 = getelementptr i32*, i32** %arr_pitch356, i32 0
  %malloccall358 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array359 = bitcast i8* %malloccall358 to i32*
  %prefield_elem360 = getelementptr i32, i32* %array359, i32 0
  store i32 0, i32* %prefield_elem360
  %scaledegreer_elem361 = getelementptr i32, i32* %array359, i32 1
  store i32 1, i32* %scaledegreer_elem361
  %postfield_elem362 = getelementptr i32, i32* %array359, i32 2
  store i32 0, i32* %postfield_elem362
  store i32* %array359, i32** %pitch_pointer_elem357
  %struct_c_pointer363 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct353, i32 0, i32 1
  store i32** %arr_pitch356, i32*** %struct_c_pointer363
  %actual_chord_struct364 = load %chord_struct,
%chord_struct* %chord_struct353
  store %chord_struct %actual_chord_struct364, %chord_struct*
%pointer_chord_elem_list351
  %pointer_chord_elem_list365 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 25
  %malloccall366 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct367 = bitcast i8* %malloccall366 to
%chord_struct*
  %length368 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct367, i32 0, i32 0
  store i32 1, i32* %length368
  %malloccall369 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch370 = bitcast i8* %malloccall369 to i32**
  %pitch_pointer_elem371 = getelementptr i32*, i32**
%arr_pitch370, i32 0
  %malloccall372 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array373 = bitcast i8* %malloccall372 to i32*
  %prefield_elem374 = getelementptr i32, i32* %array373, i32
0
  store i32 -1, i32* %prefield_elem374
  %scaledegreer_elem375 = getelementptr i32, i32* %array373,
i32 1
  store i32 7, i32* %scaledegreer_elem375
  %postfield_elem376 = getelementptr i32, i32* %array373, i32
2
  store i32 -1, i32* %postfield_elem376
  store i32* %array373, i32** %pitch_pointer_elem371
  %struct_c_pointer377 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct367, i32 0, i32 1
  store i32** %arr_pitch370, i32*** %struct_c_pointer377
  %actual_chord_struct378 = load %chord_struct,
%chord_struct* %chord_struct367
  store %chord_struct %actual_chord_struct378, %chord_struct*
%pointer_chord_elem_list365
  %pointer_chord_elem_list379 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array, i32 26
  %malloccall380 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct381 = bitcast i8* %malloccall380 to %chord_struct*
  %length382 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct381, i32 0, i32 0
  store i32 1, i32* %length382
  %malloccall383 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch384 = bitcast i8* %malloccall383 to i32**
  %pitch_pointer_elem385 = getelementptr i32*, i32** %arr_pitch384, i32 0
  %malloccall386 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array387 = bitcast i8* %malloccall386 to i32*
  %prefield_elem388 = getelementptr i32, i32* %array387, i32 0
  store i32 0, i32* %prefield_elem388
  %scaledegreer_elem389 = getelementptr i32, i32* %array387, i32 1
  store i32 5, i32* %scaledegreer_elem389
  %postfield_elem390 = getelementptr i32, i32* %array387, i32 2
  store i32 0, i32* %postfield_elem390
  store i32* %array387, i32** %pitch_pointer_elem385
  %struct_c_pointer391 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct381, i32 0, i32 1
  store i32** %arr_pitch384, i32*** %struct_c_pointer391
  %actual_chord_struct392 = load %chord_struct, %chord_struct* %chord_struct381
  store %chord_struct %actual_chord_struct392, %chord_struct* %pointer_chord_elem_list379
  %struct_cl_pointer = getelementptr inbounds %chordlist_struct, %chordlist_struct* %cl_struct, i32 0, i32 1
  store %chord_struct* %chord_pointer_array, %chord_struct** %struct_cl_pointer
  %theme = alloca %chordlist_struct*
  store %chordlist_struct* %cl_struct, %chordlist_struct**
```

```
%theme
  %array_struct393 = alloca %list_struct_f
  %length394 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct393, i32 0, i32 0
  store i32 27, i32* %length394
  %array395 = alloca double, i32 27
  %elem396 = getelementptr double, double* %array395, i32 0
  store double 0.000000e+00, double* %elem396
  %elem397 = getelementptr double, double* %array395, i32 1
  store double 1.000000e-01, double* %elem397
  %elem398 = getelementptr double, double* %array395, i32 2
  store double 1.000000e-01, double* %elem398
  %elem399 = getelementptr double, double* %array395, i32 3
  store double 1.000000e-01, double* %elem399
  %elem400 = getelementptr double, double* %array395, i32 4
  store double 1.000000e-01, double* %elem400
  %elem401 = getelementptr double, double* %array395, i32 5
  store double 1.000000e-01, double* %elem401
  %elem402 = getelementptr double, double* %array395, i32 6
  store double 1.000000e-01, double* %elem402
  %elem403 = getelementptr double, double* %array395, i32 7
  store double 1.000000e-01, double* %elem403
  %elem404 = getelementptr double, double* %array395, i32 8
  store double 1.000000e-01, double* %elem404
  %elem405 = getelementptr double, double* %array395, i32 9
  store double 1.000000e-01, double* %elem405
  %elem406 = getelementptr double, double* %array395, i32 10
  store double 1.000000e-01, double* %elem406
  %elem407 = getelementptr double, double* %array395, i32 11
  store double 1.000000e-01, double* %elem407
  %elem408 = getelementptr double, double* %array395, i32 12
  store double 1.000000e-01, double* %elem408
  %elem409 = getelementptr double, double* %array395, i32 13
  store double 1.000000e-01, double* %elem409
  %elem410 = getelementptr double, double* %array395, i32 14
  store double 1.000000e-01, double* %elem410
  %elem411 = getelementptr double, double* %array395, i32 15
  store double 1.000000e-01, double* %elem411
  %elem412 = getelementptr double, double* %array395, i32 16
  store double 1.000000e-01, double* %elem412
  %elem413 = getelementptr double, double* %array395, i32 17
  store double 1.000000e-01, double* %elem413
  %elem414 = getelementptr double, double* %array395, i32 18
  store double 1.000000e-01, double* %elem414
  %elem415 = getelementptr double, double* %array395, i32 19
  store double 1.000000e-01, double* %elem415
  %elem416 = getelementptr double, double* %array395, i32 20
  store double 1.000000e-01, double* %elem416
  %elem417 = getelementptr double, double* %array395, i32 21
  store double 1.000000e-01, double* %elem417
  %elem418 = getelementptr double, double* %array395, i32 22
  store double 1.000000e-01, double* %elem418
  %elem419 = getelementptr double, double* %array395, i32 23
  store double 1.000000e-01, double* %elem419
  %elem420 = getelementptr double, double* %array395, i32 24
  store double 1.000000e-01, double* %elem420
  %elem421 = getelementptr double, double* %array395, i32 25
  store double 2.000000e-01, double* %elem421
  %elem422 = getelementptr double, double* %array395, i32 26
  store double 2.000000e-01, double* %elem422
  %actual_list423 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct393, i32 0, i32 1
  store double* %array395, double** %actual_list423
  %r1 = alloca %list_struct_f*
  store %list_struct_f* %array_struct393, %list_struct_f**
%r1
  %array_struct424 = alloca %list_struct_f
  %length425 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct424, i32 0, i32 0
  store i32 27, i32* %length425
  %array426 = alloca double, i32 27
  %elem427 = getelementptr double, double* %array426, i32 0
  store double 2.500000e+00, double* %elem427
  %elem428 = getelementptr double, double* %array426, i32 1
  store double 1.000000e-01, double* %elem428
  %elem429 = getelementptr double, double* %array426, i32 2
  store double 1.000000e-01, double* %elem429
  %elem430 = getelementptr double, double* %array426, i32 3
  store double 1.000000e-01, double* %elem430
  %elem431 = getelementptr double, double* %array426, i32 4
  store double 1.000000e-01, double* %elem431
  %elem432 = getelementptr double, double* %array426, i32 5
  store double 1.000000e-01, double* %elem432
  %elem433 = getelementptr double, double* %array426, i32 6
```

```
store double 1.000000e-01, double* %elem433
%elem434 = getelementptr double, double* %array426, i32 7
store double 1.000000e-01, double* %elem434
%elem435 = getelementptr double, double* %array426, i32 8
store double 1.000000e-01, double* %elem435
%elem436 = getelementptr double, double* %array426, i32 9
store double 1.000000e-01, double* %elem436
%elem437 = getelementptr double, double* %array426, i32 10
store double 1.000000e-01, double* %elem437
%elem438 = getelementptr double, double* %array426, i32 11
store double 1.000000e-01, double* %elem438
%elem439 = getelementptr double, double* %array426, i32 12
store double 1.000000e-01, double* %elem439
%elem440 = getelementptr double, double* %array426, i32 13
store double 1.000000e-01, double* %elem440
%elem441 = getelementptr double, double* %array426, i32 14
store double 1.000000e-01, double* %elem441
%elem442 = getelementptr double, double* %array426, i32 15
store double 1.000000e-01, double* %elem442
%elem443 = getelementptr double, double* %array426, i32 16
store double 1.000000e-01, double* %elem443
%elem444 = getelementptr double, double* %array426, i32 17
store double 1.000000e-01, double* %elem444
%elem445 = getelementptr double, double* %array426, i32 18
store double 1.000000e-01, double* %elem445
%elem446 = getelementptr double, double* %array426, i32 19
store double 1.000000e-01, double* %elem446
%elem447 = getelementptr double, double* %array426, i32 20
store double 1.000000e-01, double* %elem447
%elem448 = getelementptr double, double* %array426, i32 21
store double 1.000000e-01, double* %elem448
%elem449 = getelementptr double, double* %array426, i32 22
store double 1.000000e-01, double* %elem449
%elem450 = getelementptr double, double* %array426, i32 23
store double 1.000000e-01, double* %elem450
%elem451 = getelementptr double, double* %array426, i32 24
store double 1.000000e-01, double* %elem451
%elem452 = getelementptr double, double* %array426, i32 25
store double 2.000000e-01, double* %elem452
%elem453 = getelementptr double, double* %array426, i32 26
store double 2.000000e-01, double* %elem453
%actual_list454 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct424, i32 0, i32 1
  store double* %array426, double** %actual_list454
  %r2 = alloca %list_struct_f*
  store %list_struct_f* %array_struct424, %list_struct_f**
%r2
  %malloccall455 = tail call i8* @malloc(i32 ptrtoint
(%chordlist_struct* getelementptr (%chordlist_struct,
%chordlist_struct* null, i32 1) to i32))
  %cl_struct456 = bitcast i8* %malloccall455 to
%chordlist_struct*
  %length457 = getelementptr inbounds %chordlist_struct,
%chordlist_struct* %cl_struct456, i32 0, i32 0
  store i32 16, i32* %length457
  %malloccall458 = tail call i8* @malloc(i32 mul (i32
ptrtoint (%chord_struct* getelementptr (%chord_struct,
%chord_struct* null, i32 1) to i32), i32 16))
  %chord_pointer_array459 = bitcast i8* %malloccall458 to
%chord_struct*
  %pointer_chord_elem_list460 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 0
  %malloccall461 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct462 = bitcast i8* %malloccall461 to
%chord_struct*
  %length463 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct462, i32 0, i32 0
  store i32 1, i32* %length463
  %malloccall464 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch465 = bitcast i8* %malloccall464 to i32**
  %pitch_pointer_elem466 = getelementptr i32*, i32**
%arr_pitch465, i32 0
  %malloccall467 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array468 = bitcast i8* %malloccall467 to i32*
  %prefield_elem469 = getelementptr i32, i32* %array468, i32
0
  store i32 0, i32* %prefield_elem469
  %scaledegreer_elem470 = getelementptr i32, i32* %array468,
i32 1
```

```
  store i32 0, i32* %scaledegreer_elem470
  %postfield_elem471 = getelementptr i32, i32* %array468, i32 2
  store i32 0, i32* %postfield_elem471
  store i32* %array468, i32** %pitch_pointer_elem466
  %struct_c_pointer472 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct462, i32 0, i32 1
  store i32** %arr_pitch465, i32*** %struct_c_pointer472
  %actual_chord_struct473 = load %chord_struct, %chord_struct* %chord_struct462
  store %chord_struct %actual_chord_struct473, %chord_struct* %pointer_chord_elem_list460
  %pointer_chord_elem_list474 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 1
  %malloccall475 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct476 = bitcast i8* %malloccall475 to %chord_struct*
  %length477 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct476, i32 0, i32 0
  store i32 1, i32* %length477
  %malloccall478 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch479 = bitcast i8* %malloccall478 to i32**
  %pitch_pointer_elem480 = getelementptr i32*, i32** %arr_pitch479, i32 0
  %malloccall481 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array482 = bitcast i8* %malloccall481 to i32*
  %prefield_elem483 = getelementptr i32, i32* %array482, i32 0
  store i32 0, i32* %prefield_elem483
  %scaledegreer_elem484 = getelementptr i32, i32* %array482, i32 1
  store i32 5, i32* %scaledegreer_elem484
  %postfield_elem485 = getelementptr i32, i32* %array482, i32 2
  store i32 0, i32* %postfield_elem485
  store i32* %array482, i32** %pitch_pointer_elem480
  %struct_c_pointer486 = getelementptr inbounds
```

```
%chord_struct, %chord_struct* %chord_struct476, i32 0, i32 1
  store i32** %arr_pitch479, i32*** %struct_c_pointer486
  %actual_chord_struct487 = load %chord_struct,
%chord_struct* %chord_struct476
  store %chord_struct %actual_chord_struct487, %chord_struct*
%pointer_chord_elem_list474
  %pointer_chord_elem_list488 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 2
  %malloccall489 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct490 = bitcast i8* %malloccall489 to
%chord_struct*
  %length491 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct490, i32 0, i32 0
  store i32 1, i32* %length491
  %malloccall492 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch493 = bitcast i8* %malloccall492 to i32**
  %pitch_pointer_elem494 = getelementptr i32*, i32**
%arr_pitch493, i32 0
  %malloccall495 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array496 = bitcast i8* %malloccall495 to i32*
  %prefield_elem497 = getelementptr i32, i32* %array496, i32
0
  store i32 0, i32* %prefield_elem497
  %scaledegreer_elem498 = getelementptr i32, i32* %array496,
i32 1
  store i32 6, i32* %scaledegreer_elem498
  %postfield_elem499 = getelementptr i32, i32* %array496, i32
2
  store i32 0, i32* %postfield_elem499
  store i32* %array496, i32** %pitch_pointer_elem494
  %struct_c_pointer500 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct490, i32 0, i32 1
  store i32** %arr_pitch493, i32*** %struct_c_pointer500
  %actual_chord_struct501 = load %chord_struct,
%chord_struct* %chord_struct490
  store %chord_struct %actual_chord_struct501, %chord_struct*
%pointer_chord_elem_list488
```

```
  %pointer_chord_elem_list502 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 3
  %malloccall503 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct504 = bitcast i8* %malloccall503 to %chord_struct*
  %length505 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct504, i32 0, i32 0
  store i32 1, i32* %length505
  %malloccall506 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch507 = bitcast i8* %malloccall506 to i32**
  %pitch_pointer_elem508 = getelementptr i32*, i32** %arr_pitch507, i32 0
  %malloccall509 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array510 = bitcast i8* %malloccall509 to i32*
  %prefield_elem511 = getelementptr i32, i32* %array510, i32 0
  store i32 0, i32* %prefield_elem511
  %scaledegreer_elem512 = getelementptr i32, i32* %array510, i32 1
  store i32 5, i32* %scaledegreer_elem512
  %postfield_elem513 = getelementptr i32, i32* %array510, i32 2
  store i32 0, i32* %postfield_elem513
  store i32* %array510, i32** %pitch_pointer_elem508
  %struct_c_pointer514 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct504, i32 0, i32 1
  store i32** %arr_pitch507, i32*** %struct_c_pointer514
  %actual_chord_struct515 = load %chord_struct, %chord_struct* %chord_struct504
  store %chord_struct %actual_chord_struct515, %chord_struct* %pointer_chord_elem_list502
  %pointer_chord_elem_list516 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 4
  %malloccall517 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct518 = bitcast i8* %malloccall517 to
```

```
%chord_struct*
  %length519 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct518, i32 0, i32 0
  store i32 1, i32* %length519
  %malloccall520 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch521 = bitcast i8* %malloccall520 to i32**
  %pitch_pointer_elem522 = getelementptr i32*, i32**
%arr_pitch521, i32 0
  %malloccall523 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array524 = bitcast i8* %malloccall523 to i32*
  %prefield_elem525 = getelementptr i32, i32* %array524, i32
0
  store i32 0, i32* %prefield_elem525
  %scaledegreer_elem526 = getelementptr i32, i32* %array524,
i32 1
  store i32 4, i32* %scaledegreer_elem526
  %postfield_elem527 = getelementptr i32, i32* %array524, i32
2
  store i32 0, i32* %postfield_elem527
  store i32* %array524, i32** %pitch_pointer_elem522
  %struct_c_pointer528 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct518, i32 0, i32 1
  store i32** %arr_pitch521, i32*** %struct_c_pointer528
  %actual_chord_struct529 = load %chord_struct,
%chord_struct* %chord_struct518
  store %chord_struct %actual_chord_struct529, %chord_struct*
%pointer_chord_elem_list516
  %pointer_chord_elem_list530 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 5
  %malloccall531 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct532 = bitcast i8* %malloccall531 to
%chord_struct*
  %length533 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct532, i32 0, i32 0
  store i32 1, i32* %length533
  %malloccall534 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
```

```
  %arr_pitch535 = bitcast i8* %malloccall534 to i32**
  %pitch_pointer_elem536 = getelementptr i32*, i32** %arr_pitch535, i32 0
  %malloccall537 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array538 = bitcast i8* %malloccall537 to i32*
  %prefield_elem539 = getelementptr i32, i32* %array538, i32 0
  store i32 0, i32* %prefield_elem539
  %scaledegreer_elem540 = getelementptr i32, i32* %array538, i32 1
  store i32 3, i32* %scaledegreer_elem540
  %postfield_elem541 = getelementptr i32, i32* %array538, i32 2
  store i32 0, i32* %postfield_elem541
  store i32* %array538, i32** %pitch_pointer_elem536
  %struct_c_pointer542 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct532, i32 0, i32 1
  store i32** %arr_pitch535, i32*** %struct_c_pointer542
  %actual_chord_struct543 = load %chord_struct, %chord_struct* %chord_struct532
  store %chord_struct %actual_chord_struct543, %chord_struct* %pointer_chord_elem_list530
  %pointer_chord_elem_list544 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 6
  %malloccall545 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct546 = bitcast i8* %malloccall545 to %chord_struct*
  %length547 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct546, i32 0, i32 0
  store i32 1, i32* %length547
  %malloccall548 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch549 = bitcast i8* %malloccall548 to i32**
  %pitch_pointer_elem550 = getelementptr i32*, i32** %arr_pitch549, i32 0
  %malloccall551 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array552 = bitcast i8* %malloccall551 to i32*
  %prefield_elem553 = getelementptr i32, i32* %array552, i32 0
  store i32 0, i32* %prefield_elem553
  %scaledegreer_elem554 = getelementptr i32, i32* %array552, i32 1
  store i32 2, i32* %scaledegreer_elem554
  %postfield_elem555 = getelementptr i32, i32* %array552, i32 2
  store i32 0, i32* %postfield_elem555
  store i32* %array552, i32** %pitch_pointer_elem550
  %struct_c_pointer556 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct546, i32 0, i32 1
  store i32** %arr_pitch549, i32*** %struct_c_pointer556
  %actual_chord_struct557 = load %chord_struct, %chord_struct* %chord_struct546
  store %chord_struct %actual_chord_struct557, %chord_struct* %pointer_chord_elem_list544
  %pointer_chord_elem_list558 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 7
  %malloccall559 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct560 = bitcast i8* %malloccall559 to %chord_struct*
  %length561 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct560, i32 0, i32 0
  store i32 1, i32* %length561
  %malloccall562 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch563 = bitcast i8* %malloccall562 to i32**
  %pitch_pointer_elem564 = getelementptr i32*, i32** %arr_pitch563, i32 0
  %malloccall565 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array566 = bitcast i8* %malloccall565 to i32*
  %prefield_elem567 = getelementptr i32, i32* %array566, i32 0
  store i32 0, i32* %prefield_elem567
  %scaledegreer_elem568 = getelementptr i32, i32* %array566, i32 1
  store i32 4, i32* %scaledegreer_elem568
  %postfield_elem569 = getelementptr i32, i32* %array566, i32 2
  store i32 0, i32* %postfield_elem569
  store i32* %array566, i32** %pitch_pointer_elem564
  %struct_c_pointer570 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct560, i32 0, i32 1
  store i32** %arr_pitch563, i32*** %struct_c_pointer570
  %actual_chord_struct571 = load %chord_struct, %chord_struct* %chord_struct560
  store %chord_struct %actual_chord_struct571, %chord_struct* %pointer_chord_elem_list558
  %pointer_chord_elem_list572 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 8
  %malloccall573 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct574 = bitcast i8* %malloccall573 to %chord_struct*
  %length575 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct574, i32 0, i32 0
  store i32 1, i32* %length575
  %malloccall576 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch577 = bitcast i8* %malloccall576 to i32**
  %pitch_pointer_elem578 = getelementptr i32*, i32** %arr_pitch577, i32 0
  %malloccall579 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array580 = bitcast i8* %malloccall579 to i32*
  %prefield_elem581 = getelementptr i32, i32* %array580, i32 0
  store i32 0, i32* %prefield_elem581
  %scaledegreer_elem582 = getelementptr i32, i32* %array580, i32 1
  store i32 3, i32* %scaledegreer_elem582
  %postfield_elem583 = getelementptr i32, i32* %array580, i32 2
  store i32 0, i32* %postfield_elem583
  store i32* %array580, i32** %pitch_pointer_elem578
  %struct_c_pointer584 = getelementptr inbounds
```

```
%chord_struct, %chord_struct* %chord_struct574, i32 0, i32 1
  store i32** %arr_pitch577, i32*** %struct_c_pointer584
  %actual_chord_struct585 = load %chord_struct,
%chord_struct* %chord_struct574
  store %chord_struct %actual_chord_struct585, %chord_struct*
%pointer_chord_elem_list572
  %pointer_chord_elem_list586 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 9
  %malloccall587 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct588 = bitcast i8* %malloccall587 to
%chord_struct*
  %length589 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct588, i32 0, i32 0
  store i32 1, i32* %length589
  %malloccall590 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch591 = bitcast i8* %malloccall590 to i32**
  %pitch_pointer_elem592 = getelementptr i32*, i32**
%arr_pitch591, i32 0
  %malloccall593 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array594 = bitcast i8* %malloccall593 to i32*
  %prefield_elem595 = getelementptr i32, i32* %array594, i32
0
  store i32 0, i32* %prefield_elem595
  %scaledegreer_elem596 = getelementptr i32, i32* %array594,
i32 1
  store i32 2, i32* %scaledegreer_elem596
  %postfield_elem597 = getelementptr i32, i32* %array594, i32
2
  store i32 0, i32* %postfield_elem597
  store i32* %array594, i32** %pitch_pointer_elem592
  %struct_c_pointer598 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct588, i32 0, i32 1
  store i32** %arr_pitch591, i32*** %struct_c_pointer598
  %actual_chord_struct599 = load %chord_struct,
%chord_struct* %chord_struct588
  store %chord_struct %actual_chord_struct599, %chord_struct*
%pointer_chord_elem_list586
```

```
  %pointer_chord_elem_list600 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 10
  %malloccall601 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct602 = bitcast i8* %malloccall601 to %chord_struct*
  %length603 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct602, i32 0, i32 0
  store i32 1, i32* %length603
  %malloccall604 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch605 = bitcast i8* %malloccall604 to i32**
  %pitch_pointer_elem606 = getelementptr i32*, i32** %arr_pitch605, i32 0
  %malloccall607 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array608 = bitcast i8* %malloccall607 to i32*
  %prefield_elem609 = getelementptr i32, i32* %array608, i32 0
  store i32 0, i32* %prefield_elem609
  %scaledegreer_elem610 = getelementptr i32, i32* %array608, i32 1
  store i32 1, i32* %scaledegreer_elem610
  %postfield_elem611 = getelementptr i32, i32* %array608, i32 2
  store i32 0, i32* %postfield_elem611
  store i32* %array608, i32** %pitch_pointer_elem606
  %struct_c_pointer612 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct602, i32 0, i32 1
  store i32** %arr_pitch605, i32*** %struct_c_pointer612
  %actual_chord_struct613 = load %chord_struct, %chord_struct* %chord_struct602
  store %chord_struct %actual_chord_struct613, %chord_struct* %pointer_chord_elem_list600
  %pointer_chord_elem_list614 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 11
  %malloccall615 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct616 = bitcast i8* %malloccall615 to
```

```
%chord_struct*
  %length617 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct616, i32 0, i32 0
  store i32 1, i32* %length617
  %malloccall618 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch619 = bitcast i8* %malloccall618 to i32**
  %pitch_pointer_elem620 = getelementptr i32*, i32** %arr_pitch619, i32 0
  %malloccall621 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array622 = bitcast i8* %malloccall621 to i32*
  %prefield_elem623 = getelementptr i32, i32* %array622, i32 0
  store i32 -1, i32* %prefield_elem623
  %scaledegreer_elem624 = getelementptr i32, i32* %array622, i32 1
  store i32 7, i32* %scaledegreer_elem624
  %postfield_elem625 = getelementptr i32, i32* %array622, i32 2
  store i32 0, i32* %postfield_elem625
  store i32* %array622, i32** %pitch_pointer_elem620
  %struct_c_pointer626 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct616, i32 0, i32 1
  store i32** %arr_pitch619, i32*** %struct_c_pointer626
  %actual_chord_struct627 = load %chord_struct, %chord_struct* %chord_struct616
  store %chord_struct %actual_chord_struct627, %chord_struct* %pointer_chord_elem_list614
  %pointer_chord_elem_list628 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 12
  %malloccall629 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct630 = bitcast i8* %malloccall629 to %chord_struct*
  %length631 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct630, i32 0, i32 0
  store i32 1, i32* %length631
  %malloccall632 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch633 = bitcast i8* %malloccall632 to i32**
  %pitch_pointer_elem634 = getelementptr i32*, i32**
%arr_pitch633, i32 0
  %malloccall635 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array636 = bitcast i8* %malloccall635 to i32*
  %prefield_elem637 = getelementptr i32, i32* %array636, i32
0
  store i32 0, i32* %prefield_elem637
  %scaledegreer_elem638 = getelementptr i32, i32* %array636,
i32 1
  store i32 1, i32* %scaledegreer_elem638
  %postfield_elem639 = getelementptr i32, i32* %array636, i32
2
  store i32 0, i32* %postfield_elem639
  store i32* %array636, i32** %pitch_pointer_elem634
  %struct_c_pointer640 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct630, i32 0, i32 1
  store i32** %arr_pitch633, i32*** %struct_c_pointer640
  %actual_chord_struct641 = load %chord_struct,
%chord_struct* %chord_struct630
  store %chord_struct %actual_chord_struct641, %chord_struct*
%pointer_chord_elem_list628
  %pointer_chord_elem_list642 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 13
  %malloccall643 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct644 = bitcast i8* %malloccall643 to
%chord_struct*
  %length645 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct644, i32 0, i32 0
  store i32 1, i32* %length645
  %malloccall646 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch647 = bitcast i8* %malloccall646 to i32**
  %pitch_pointer_elem648 = getelementptr i32*, i32**
%arr_pitch647, i32 0
  %malloccall649 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
```

```
  %array650 = bitcast i8* %malloccall649 to i32*
  %prefield_elem651 = getelementptr i32, i32* %array650, i32 0
  store i32 0, i32* %prefield_elem651
  %scaledegreer_elem652 = getelementptr i32, i32* %array650, i32 1
  store i32 2, i32* %scaledegreer_elem652
  %postfield_elem653 = getelementptr i32, i32* %array650, i32 2
  store i32 0, i32* %postfield_elem653
  store i32* %array650, i32** %pitch_pointer_elem648
  %struct_c_pointer654 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct644, i32 0, i32 1
  store i32** %arr_pitch647, i32*** %struct_c_pointer654
  %actual_chord_struct655 = load %chord_struct, %chord_struct* %chord_struct644
  store %chord_struct %actual_chord_struct655, %chord_struct* %pointer_chord_elem_list642
  %pointer_chord_elem_list656 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array459, i32 14
  %malloccall657 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct658 = bitcast i8* %malloccall657 to %chord_struct*
  %length659 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct658, i32 0, i32 0
  store i32 1, i32* %length659
  %malloccall660 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch661 = bitcast i8* %malloccall660 to i32**
  %pitch_pointer_elem662 = getelementptr i32*, i32** %arr_pitch661, i32 0
  %malloccall663 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array664 = bitcast i8* %malloccall663 to i32*
  %prefield_elem665 = getelementptr i32, i32* %array664, i32 0
  store i32 -1, i32* %prefield_elem665
  %scaledegreer_elem666 = getelementptr i32, i32* %array664, i32 1
  store i32 7, i32* %scaledegreer_elem666
  %postfield_elem667 = getelementptr i32, i32* %array664, i32
2
  store i32 0, i32* %postfield_elem667
  store i32* %array664, i32** %pitch_pointer_elem662
  %struct_c_pointer668 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct658, i32 0, i32 1
  store i32** %arr_pitch661, i32*** %struct_c_pointer668
  %actual_chord_struct669 = load %chord_struct,
%chord_struct* %chord_struct658
  store %chord_struct %actual_chord_struct669, %chord_struct*
%pointer_chord_elem_list656
  %pointer_chord_elem_list670 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array459, i32 15
  %malloccall671 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct672 = bitcast i8* %malloccall671 to
%chord_struct*
  %length673 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct672, i32 0, i32 0
  store i32 1, i32* %length673
  %malloccall674 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch675 = bitcast i8* %malloccall674 to i32**
  %pitch_pointer_elem676 = getelementptr i32*, i32**
%arr_pitch675, i32 0
  %malloccall677 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array678 = bitcast i8* %malloccall677 to i32*
  %prefield_elem679 = getelementptr i32, i32* %array678, i32
0
  store i32 0, i32* %prefield_elem679
  %scaledegreer_elem680 = getelementptr i32, i32* %array678,
i32 1
  store i32 1, i32* %scaledegreer_elem680
  %postfield_elem681 = getelementptr i32, i32* %array678, i32
2
  store i32 0, i32* %postfield_elem681
  store i32* %array678, i32** %pitch_pointer_elem676
  %struct_c_pointer682 = getelementptr inbounds
```

```
%chord_struct, %chord_struct* %chord_struct672, i32 0, i32 1
  store i32** %arr_pitch675, i32*** %struct_c_pointer682
  %actual_chord_struct683 = load %chord_struct,
%chord_struct* %chord_struct672
  store %chord_struct %actual_chord_struct683, %chord_struct*
%pointer_chord_elem_list670
  %struct_cl_pointer684 = getelementptr inbounds
%chordlist_struct, %chordlist_struct* %cl_struct456, i32 0,
i32 1
  store %chord_struct* %chord_pointer_array459,
%chord_struct** %struct_cl_pointer684
  %counter = alloca %chordlist_struct*
  store %chordlist_struct* %cl_struct456, %chordlist_struct**
%counter
  %array_struct685 = alloca %list_struct_f
  %length686 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct685, i32 0, i32 0
  store i32 16, i32* %length686
  %array687 = alloca double, i32 16
  %elem688 = getelementptr double, double* %array687, i32 0
  store double 1.000000e-01, double* %elem688
  %elem689 = getelementptr double, double* %array687, i32 1
  store double 1.000000e-01, double* %elem689
  %elem690 = getelementptr double, double* %array687, i32 2
  store double 1.000000e-01, double* %elem690
  %elem691 = getelementptr double, double* %array687, i32 3
  store double 1.000000e-01, double* %elem691
  %elem692 = getelementptr double, double* %array687, i32 4
  store double 1.000000e-01, double* %elem692
  %elem693 = getelementptr double, double* %array687, i32 5
  store double 1.000000e-01, double* %elem693
  %elem694 = getelementptr double, double* %array687, i32 6
  store double 1.000000e-01, double* %elem694
  %elem695 = getelementptr double, double* %array687, i32 7
  store double 1.000000e-01, double* %elem695
  %elem696 = getelementptr double, double* %array687, i32 8
  store double 5.000000e-01, double* %elem696
  %elem697 = getelementptr double, double* %array687, i32 9
  store double 1.000000e-01, double* %elem697
  %elem698 = getelementptr double, double* %array687, i32 10
  store double 1.000000e-01, double* %elem698
  %elem699 = getelementptr double, double* %array687, i32 11
  store double 1.000000e-01, double* %elem699
  %elem700 = getelementptr double, double* %array687, i32 12
  store double 1.000000e-01, double* %elem700
  %elem701 = getelementptr double, double* %array687, i32 13
  store double 1.000000e-01, double* %elem701
  %elem702 = getelementptr double, double* %array687, i32 14
  store double 1.000000e-01, double* %elem702
  %elem703 = getelementptr double, double* %array687, i32 15
  store double 1.000000e-01, double* %elem703
  %actual_list704 = getelementptr inbounds %list_struct_f, %list_struct_f* %array_struct685, i32 0, i32 1
  store double* %array687, double** %actual_list704
  %r3 = alloca %list_struct_f*
  store %list_struct_f* %array_struct685, %list_struct_f** %r3
  %malloccall705 = tail call i8* @malloc(i32 ptrtoint (%chordlist_struct* getelementptr (%chordlist_struct, %chordlist_struct* null, i32 1) to i32))
  %cl_struct706 = bitcast i8* %malloccall705 to %chordlist_struct*
  %length707 = getelementptr inbounds %chordlist_struct, %chordlist_struct* %cl_struct706, i32 0, i32 0
  store i32 21, i32* %length707
  %malloccall708 = tail call i8* @malloc(i32 mul (i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32), i32 21))
  %chord_pointer_array709 = bitcast i8* %malloccall708 to %chord_struct*
  %pointer_chord_elem_list710 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 0
  %malloccall711 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct712 = bitcast i8* %malloccall711 to %chord_struct*
  %length713 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct712, i32 0, i32 0
  store i32 1, i32* %length713
  %malloccall714 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch715 = bitcast i8* %malloccall714 to i32**
  %pitch_pointer_elem716 = getelementptr i32*, i32**
```

```
%arr_pitch715, i32 0
  %malloccall717 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array718 = bitcast i8* %malloccall717 to i32*
  %prefield_elem719 = getelementptr i32, i32* %array718, i32 0
  store i32 0, i32* %prefield_elem719
  %scaledegreer_elem720 = getelementptr i32, i32* %array718, i32 1
  store i32 0, i32* %scaledegreer_elem720
  %postfield_elem721 = getelementptr i32, i32* %array718, i32 2
  store i32 0, i32* %postfield_elem721
  store i32* %array718, i32** %pitch_pointer_elem716
  %struct_c_pointer722 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct712, i32 0, i32 1
  store i32** %arr_pitch715, i32*** %struct_c_pointer722
  %actual_chord_struct723 = load %chord_struct, %chord_struct* %chord_struct712
  store %chord_struct %actual_chord_struct723, %chord_struct* %pointer_chord_elem_list710
  %pointer_chord_elem_list724 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 1
  %malloccall725 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct726 = bitcast i8* %malloccall725 to %chord_struct*
  %length727 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct726, i32 0, i32 0
  store i32 1, i32* %length727
  %malloccall728 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch729 = bitcast i8* %malloccall728 to i32**
  %pitch_pointer_elem730 = getelementptr i32*, i32** %arr_pitch729, i32 0
  %malloccall731 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array732 = bitcast i8* %malloccall731 to i32*
  %prefield_elem733 = getelementptr i32, i32* %array732, i32
```

```
0
  store i32 -1, i32* %prefield_elem733
  %scaledegreer_elem734 = getelementptr i32, i32* %array732,
i32 1
  store i32 5, i32* %scaledegreer_elem734
  %postfield_elem735 = getelementptr i32, i32* %array732, i32
2
  store i32 0, i32* %postfield_elem735
  store i32* %array732, i32** %pitch_pointer_elem730
  %struct_c_pointer736 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct726, i32 0, i32 1
  store i32** %arr_pitch729, i32*** %struct_c_pointer736
  %actual_chord_struct737 = load %chord_struct,
%chord_struct* %chord_struct726
  store %chord_struct %actual_chord_struct737, %chord_struct*
%pointer_chord_elem_list724
  %pointer_chord_elem_list738 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 2
  %malloccall739 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct740 = bitcast i8* %malloccall739 to
%chord_struct*
  %length741 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct740, i32 0, i32 0
  store i32 1, i32* %length741
  %malloccall742 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch743 = bitcast i8* %malloccall742 to i32**
  %pitch_pointer_elem744 = getelementptr i32*, i32**
%arr_pitch743, i32 0
  %malloccall745 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array746 = bitcast i8* %malloccall745 to i32*
  %prefield_elem747 = getelementptr i32, i32* %array746, i32
0
  store i32 -1, i32* %prefield_elem747
  %scaledegreer_elem748 = getelementptr i32, i32* %array746,
i32 1
  store i32 7, i32* %scaledegreer_elem748
  %postfield_elem749 = getelementptr i32, i32* %array746, i32
```

```
2
  store i32 0, i32* %postfield_elem749
  store i32* %array746, i32** %pitch_pointer_elem744
  %struct_c_pointer750 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct740, i32 0, i32 1
  store i32** %arr_pitch743, i32*** %struct_c_pointer750
  %actual_chord_struct751 = load %chord_struct, %chord_struct* %chord_struct740
  store %chord_struct %actual_chord_struct751, %chord_struct* %pointer_chord_elem_list738
  %pointer_chord_elem_list752 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 3
  %malloccall753 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct754 = bitcast i8* %malloccall753 to %chord_struct*
  %length755 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct754, i32 0, i32 0
  store i32 1, i32* %length755
  %malloccall756 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch757 = bitcast i8* %malloccall756 to i32**
  %pitch_pointer_elem758 = getelementptr i32*, i32** %arr_pitch757, i32 0
  %malloccall759 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array760 = bitcast i8* %malloccall759 to i32*
  %prefield_elem761 = getelementptr i32, i32* %array760, i32 0
  store i32 0, i32* %prefield_elem761
  %scaledegreer_elem762 = getelementptr i32, i32* %array760, i32 1
  store i32 2, i32* %scaledegreer_elem762
  %postfield_elem763 = getelementptr i32, i32* %array760, i32 2
  store i32 0, i32* %postfield_elem763
  store i32* %array760, i32** %pitch_pointer_elem758
  %struct_c_pointer764 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct754, i32 0, i32 1
  store i32** %arr_pitch757, i32*** %struct_c_pointer764
  %actual_chord_struct765 = load %chord_struct, %chord_struct* %chord_struct754
  store %chord_struct %actual_chord_struct765, %chord_struct* %pointer_chord_elem_list752
  %pointer_chord_elem_list766 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 4
  %malloccall767 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct768 = bitcast i8* %malloccall767 to %chord_struct*
  %length769 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct768, i32 0, i32 0
  store i32 1, i32* %length769
  %malloccall770 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch771 = bitcast i8* %malloccall770 to i32**
  %pitch_pointer_elem772 = getelementptr i32*, i32** %arr_pitch771, i32 0
  %malloccall773 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array774 = bitcast i8* %malloccall773 to i32*
  %prefield_elem775 = getelementptr i32, i32* %array774, i32 0
  store i32 0, i32* %prefield_elem775
  %scaledegreer_elem776 = getelementptr i32, i32* %array774, i32 1
  store i32 4, i32* %scaledegreer_elem776
  %postfield_elem777 = getelementptr i32, i32* %array774, i32 2
  store i32 0, i32* %postfield_elem777
  store i32* %array774, i32** %pitch_pointer_elem772
  %struct_c_pointer778 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct768, i32 0, i32 1
  store i32** %arr_pitch771, i32*** %struct_c_pointer778
  %actual_chord_struct779 = load %chord_struct, %chord_struct* %chord_struct768
  store %chord_struct %actual_chord_struct779, %chord_struct* %pointer_chord_elem_list766
  %pointer_chord_elem_list780 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 5
  %malloccall781 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct782 = bitcast i8* %malloccall781 to
%chord_struct*
  %length783 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct782, i32 0, i32 0
  store i32 1, i32* %length783
  %malloccall784 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch785 = bitcast i8* %malloccall784 to i32**
  %pitch_pointer_elem786 = getelementptr i32*, i32**
%arr_pitch785, i32 0
  %malloccall787 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array788 = bitcast i8* %malloccall787 to i32*
  %prefield_elem789 = getelementptr i32, i32* %array788, i32
0
  store i32 -1, i32* %prefield_elem789
  %scaledegreer_elem790 = getelementptr i32, i32* %array788,
i32 1
  store i32 7, i32* %scaledegreer_elem790
  %postfield_elem791 = getelementptr i32, i32* %array788, i32
2
  store i32 0, i32* %postfield_elem791
  store i32* %array788, i32** %pitch_pointer_elem786
  %struct_c_pointer792 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct782, i32 0, i32 1
  store i32** %arr_pitch785, i32*** %struct_c_pointer792
  %actual_chord_struct793 = load %chord_struct,
%chord_struct* %chord_struct782
  store %chord_struct %actual_chord_struct793, %chord_struct*
%pointer_chord_elem_list780
  %pointer_chord_elem_list794 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 6
  %malloccall795 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct796 = bitcast i8* %malloccall795 to
%chord_struct*
  %length797 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct796, i32 0, i32 0
  store i32 1, i32* %length797
  %malloccall798 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch799 = bitcast i8* %malloccall798 to i32**
  %pitch_pointer_elem800 = getelementptr i32*, i32**
%arr_pitch799, i32 0
  %malloccall801 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array802 = bitcast i8* %malloccall801 to i32*
  %prefield_elem803 = getelementptr i32, i32* %array802, i32
0
  store i32 0, i32* %prefield_elem803
  %scaledegreer_elem804 = getelementptr i32, i32* %array802,
i32 1
  store i32 2, i32* %scaledegreer_elem804
  %postfield_elem805 = getelementptr i32, i32* %array802, i32
2
  store i32 0, i32* %postfield_elem805
  store i32* %array802, i32** %pitch_pointer_elem800
  %struct_c_pointer806 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct796, i32 0, i32 1
  store i32** %arr_pitch799, i32*** %struct_c_pointer806
  %actual_chord_struct807 = load %chord_struct,
%chord_struct* %chord_struct796
  store %chord_struct %actual_chord_struct807, %chord_struct*
%pointer_chord_elem_list794
  %pointer_chord_elem_list808 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 7
  %malloccall809 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct810 = bitcast i8* %malloccall809 to
%chord_struct*
  %length811 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct810, i32 0, i32 0
  store i32 1, i32* %length811
  %malloccall812 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch813 = bitcast i8* %malloccall812 to i32**
  %pitch_pointer_elem814 = getelementptr i32*, i32**
```

```
%arr_pitch813, i32 0
  %malloccall815 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array816 = bitcast i8* %malloccall815 to i32*
  %prefield_elem817 = getelementptr i32, i32* %array816, i32
0
  store i32 0, i32* %prefield_elem817
  %scaledegreer_elem818 = getelementptr i32, i32* %array816,
i32 1
  store i32 4, i32* %scaledegreer_elem818
  %postfield_elem819 = getelementptr i32, i32* %array816, i32
2
  store i32 0, i32* %postfield_elem819
  store i32* %array816, i32** %pitch_pointer_elem814
  %struct_c_pointer820 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct810, i32 0, i32 1
  store i32** %arr_pitch813, i32*** %struct_c_pointer820
  %actual_chord_struct821 = load %chord_struct,
%chord_struct* %chord_struct810
  store %chord_struct %actual_chord_struct821, %chord_struct*
%pointer_chord_elem_list808
  %pointer_chord_elem_list822 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 8
  %malloccall823 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct824 = bitcast i8* %malloccall823 to
%chord_struct*
  %length825 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct824, i32 0, i32 0
  store i32 1, i32* %length825
  %malloccall826 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch827 = bitcast i8* %malloccall826 to i32**
  %pitch_pointer_elem828 = getelementptr i32*, i32**
%arr_pitch827, i32 0
  %malloccall829 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array830 = bitcast i8* %malloccall829 to i32*
  %prefield_elem831 = getelementptr i32, i32* %array830, i32
```

```
0
  store i32 0, i32* %prefield_elem831
  %scaledegreer_elem832 = getelementptr i32, i32* %array830, i32 1
  store i32 6, i32* %scaledegreer_elem832
  %postfield_elem833 = getelementptr i32, i32* %array830, i32 2
  store i32 0, i32* %postfield_elem833
  store i32* %array830, i32** %pitch_pointer_elem828
  %struct_c_pointer834 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct824, i32 0, i32 1
  store i32** %arr_pitch827, i32*** %struct_c_pointer834
  %actual_chord_struct835 = load %chord_struct, %chord_struct* %chord_struct824
  store %chord_struct %actual_chord_struct835, %chord_struct* %pointer_chord_elem_list822
  %pointer_chord_elem_list836 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 9
  %malloccall837 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct838 = bitcast i8* %malloccall837 to %chord_struct*
  %length839 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct838, i32 0, i32 0
  store i32 1, i32* %length839
  %malloccall840 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch841 = bitcast i8* %malloccall840 to i32**
  %pitch_pointer_elem842 = getelementptr i32*, i32** %arr_pitch841, i32 0
  %malloccall843 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array844 = bitcast i8* %malloccall843 to i32*
  %prefield_elem845 = getelementptr i32, i32* %array844, i32 0
  store i32 0, i32* %prefield_elem845
  %scaledegreer_elem846 = getelementptr i32, i32* %array844, i32 1
  store i32 5, i32* %scaledegreer_elem846
  %postfield_elem847 = getelementptr i32, i32* %array844, i32
```

```
2
  store i32 0, i32* %postfield_elem847
  store i32* %array844, i32** %pitch_pointer_elem842
  %struct_c_pointer848 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct838, i32 0, i32 1
  store i32** %arr_pitch841, i32*** %struct_c_pointer848
  %actual_chord_struct849 = load %chord_struct,
%chord_struct* %chord_struct838
  store %chord_struct %actual_chord_struct849, %chord_struct*
%pointer_chord_elem_list836
  %pointer_chord_elem_list850 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 10
  %malloccall851 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct852 = bitcast i8* %malloccall851 to
%chord_struct*
  %length853 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct852, i32 0, i32 0
  store i32 1, i32* %length853
  %malloccall854 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch855 = bitcast i8* %malloccall854 to i32**
  %pitch_pointer_elem856 = getelementptr i32*, i32**
%arr_pitch855, i32 0
  %malloccall857 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array858 = bitcast i8* %malloccall857 to i32*
  %prefield_elem859 = getelementptr i32, i32* %array858, i32
0
  store i32 0, i32* %prefield_elem859
  %scaledegreer_elem860 = getelementptr i32, i32* %array858,
i32 1
  store i32 4, i32* %scaledegreer_elem860
  %postfield_elem861 = getelementptr i32, i32* %array858, i32
2
  store i32 0, i32* %postfield_elem861
  store i32* %array858, i32** %pitch_pointer_elem856
  %struct_c_pointer862 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct852, i32 0, i32 1
  store i32** %arr_pitch855, i32*** %struct_c_pointer862
  %actual_chord_struct863 = load %chord_struct, %chord_struct* %chord_struct852
  store %chord_struct %actual_chord_struct863, %chord_struct* %pointer_chord_elem_list850
  %pointer_chord_elem_list864 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 11
  %malloccall865 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct866 = bitcast i8* %malloccall865 to %chord_struct*
  %length867 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct866, i32 0, i32 0
  store i32 1, i32* %length867
  %malloccall868 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch869 = bitcast i8* %malloccall868 to i32**
  %pitch_pointer_elem870 = getelementptr i32*, i32** %arr_pitch869, i32 0
  %malloccall871 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array872 = bitcast i8* %malloccall871 to i32*
  %prefield_elem873 = getelementptr i32, i32* %array872, i32 0
  store i32 0, i32* %prefield_elem873
  %scaledegreer_elem874 = getelementptr i32, i32* %array872, i32 1
  store i32 6, i32* %scaledegreer_elem874
  %postfield_elem875 = getelementptr i32, i32* %array872, i32 2
  store i32 0, i32* %postfield_elem875
  store i32* %array872, i32** %pitch_pointer_elem870
  %struct_c_pointer876 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct866, i32 0, i32 1
  store i32** %arr_pitch869, i32*** %struct_c_pointer876
  %actual_chord_struct877 = load %chord_struct, %chord_struct* %chord_struct866
  store %chord_struct %actual_chord_struct877, %chord_struct* %pointer_chord_elem_list864
  %pointer_chord_elem_list878 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 12
  %malloccall879 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct880 = bitcast i8* %malloccall879 to
%chord_struct*
  %length881 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct880, i32 0, i32 0
  store i32 1, i32* %length881
  %malloccall882 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch883 = bitcast i8* %malloccall882 to i32**
  %pitch_pointer_elem884 = getelementptr i32*, i32**
%arr_pitch883, i32 0
  %malloccall885 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array886 = bitcast i8* %malloccall885 to i32*
  %prefield_elem887 = getelementptr i32, i32* %array886, i32
0
  store i32 0, i32* %prefield_elem887
  %scaledegreer_elem888 = getelementptr i32, i32* %array886,
i32 1
  store i32 5, i32* %scaledegreer_elem888
  %postfield_elem889 = getelementptr i32, i32* %array886, i32
2
  store i32 0, i32* %postfield_elem889
  store i32* %array886, i32** %pitch_pointer_elem884
  %struct_c_pointer890 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct880, i32 0, i32 1
  store i32** %arr_pitch883, i32*** %struct_c_pointer890
  %actual_chord_struct891 = load %chord_struct,
%chord_struct* %chord_struct880
  store %chord_struct %actual_chord_struct891, %chord_struct*
%pointer_chord_elem_list878
  %pointer_chord_elem_list892 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 13
  %malloccall893 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct894 = bitcast i8* %malloccall893 to
%chord_struct*
  %length895 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct894, i32 0, i32 0
  store i32 1, i32* %length895
  %malloccall896 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch897 = bitcast i8* %malloccall896 to i32**
  %pitch_pointer_elem898 = getelementptr i32*, i32** %arr_pitch897, i32 0
  %malloccall899 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array900 = bitcast i8* %malloccall899 to i32*
  %prefield_elem901 = getelementptr i32, i32* %array900, i32 0
  store i32 0, i32* %prefield_elem901
  %scaledegreer_elem902 = getelementptr i32, i32* %array900, i32 1
  store i32 4, i32* %scaledegreer_elem902
  %postfield_elem903 = getelementptr i32, i32* %array900, i32 2
  store i32 0, i32* %postfield_elem903
  store i32* %array900, i32** %pitch_pointer_elem898
  %struct_c_pointer904 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct894, i32 0, i32 1
  store i32** %arr_pitch897, i32*** %struct_c_pointer904
  %actual_chord_struct905 = load %chord_struct, %chord_struct* %chord_struct894
  store %chord_struct %actual_chord_struct905, %chord_struct* %pointer_chord_elem_list892
  %pointer_chord_elem_list906 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 14
  %malloccall907 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct908 = bitcast i8* %malloccall907 to %chord_struct*
  %length909 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct908, i32 0, i32 0
  store i32 1, i32* %length909
  %malloccall910 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch911 = bitcast i8* %malloccall910 to i32**
  %pitch_pointer_elem912 = getelementptr i32*, i32**
```

```
%arr_pitch911, i32 0
  %malloccall913 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array914 = bitcast i8* %malloccall913 to i32*
  %prefield_elem915 = getelementptr i32, i32* %array914, i32
0
  store i32 0, i32* %prefield_elem915
  %scaledegreer_elem916 = getelementptr i32, i32* %array914,
i32 1
  store i32 3, i32* %scaledegreer_elem916
  %postfield_elem917 = getelementptr i32, i32* %array914, i32
2
  store i32 0, i32* %postfield_elem917
  store i32* %array914, i32** %pitch_pointer_elem912
  %struct_c_pointer918 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct908, i32 0, i32 1
  store i32** %arr_pitch911, i32*** %struct_c_pointer918
  %actual_chord_struct919 = load %chord_struct,
%chord_struct* %chord_struct908
  store %chord_struct %actual_chord_struct919, %chord_struct*
%pointer_chord_elem_list906
  %pointer_chord_elem_list920 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 15
  %malloccall921 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct922 = bitcast i8* %malloccall921 to
%chord_struct*
  %length923 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct922, i32 0, i32 0
  store i32 1, i32* %length923
  %malloccall924 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch925 = bitcast i8* %malloccall924 to i32**
  %pitch_pointer_elem926 = getelementptr i32*, i32**
%arr_pitch925, i32 0
  %malloccall927 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array928 = bitcast i8* %malloccall927 to i32*
  %prefield_elem929 = getelementptr i32, i32* %array928, i32
```

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0
  store i32 0, i32* %prefield_elem929
  %scaledegreer_elem930 = getelementptr i32, i32* %array928,
i32 1
  store i32 2, i32* %scaledegreer_elem930
  %postfield_elem931 = getelementptr i32, i32* %array928, i32
2
  store i32 0, i32* %postfield_elem931
  store i32* %array928, i32** %pitch_pointer_elem926
  %struct_c_pointer932 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct922, i32 0, i32 1
  store i32** %arr_pitch925, i32*** %struct_c_pointer932
  %actual_chord_struct933 = load %chord_struct,
%chord_struct* %chord_struct922
  store %chord_struct %actual_chord_struct933, %chord_struct*
%pointer_chord_elem_list920
  %pointer_chord_elem_list934 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 16
  %malloccall935 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct936 = bitcast i8* %malloccall935 to
%chord_struct*
  %length937 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct936, i32 0, i32 0
  store i32 1, i32* %length937
  %malloccall938 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch939 = bitcast i8* %malloccall938 to i32**
  %pitch_pointer_elem940 = getelementptr i32*, i32**
%arr_pitch939, i32 0
  %malloccall941 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array942 = bitcast i8* %malloccall941 to i32*
  %prefield_elem943 = getelementptr i32, i32* %array942, i32
0
  store i32 0, i32* %prefield_elem943
  %scaledegreer_elem944 = getelementptr i32, i32* %array942,
i32 1
  store i32 1, i32* %scaledegreer_elem944
  %postfield_elem945 = getelementptr i32, i32* %array942, i32
```

```
2
  store i32 0, i32* %postfield_elem945
  store i32* %array942, i32** %pitch_pointer_elem940
  %struct_c_pointer946 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct936, i32 0, i32 1
  store i32** %arr_pitch939, i32*** %struct_c_pointer946
  %actual_chord_struct947 = load %chord_struct, %chord_struct* %chord_struct936
  store %chord_struct %actual_chord_struct947, %chord_struct* %pointer_chord_elem_list934
  %pointer_chord_elem_list948 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 17
  %malloccall949 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct950 = bitcast i8* %malloccall949 to %chord_struct*
  %length951 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct950, i32 0, i32 0
  store i32 1, i32* %length951
  %malloccall952 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch953 = bitcast i8* %malloccall952 to i32**
  %pitch_pointer_elem954 = getelementptr i32*, i32** %arr_pitch953, i32 0
  %malloccall955 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array956 = bitcast i8* %malloccall955 to i32*
  %prefield_elem957 = getelementptr i32, i32* %array956, i32 0
  store i32 -1, i32* %prefield_elem957
  %scaledegreer_elem958 = getelementptr i32, i32* %array956, i32 1
  store i32 7, i32* %scaledegreer_elem958
  %postfield_elem959 = getelementptr i32, i32* %array956, i32 2
  store i32 0, i32* %postfield_elem959
  store i32* %array956, i32** %pitch_pointer_elem954
  %struct_c_pointer960 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct950, i32 0, i32 1
  store i32** %arr_pitch953, i32*** %struct_c_pointer960
  %actual_chord_struct961 = load %chord_struct, %chord_struct* %chord_struct950
  store %chord_struct %actual_chord_struct961, %chord_struct* %pointer_chord_elem_list948
  %pointer_chord_elem_list962 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 18
  %malloccall963 = tail call i8* @malloc(i32 ptrtoint (%chord_struct* getelementptr (%chord_struct, %chord_struct* null, i32 1) to i32))
  %chord_struct964 = bitcast i8* %malloccall963 to %chord_struct*
  %length965 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct964, i32 0, i32 0
  store i32 1, i32* %length965
  %malloccall966 = tail call i8* @malloc(i32 ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch967 = bitcast i8* %malloccall966 to i32**
  %pitch_pointer_elem968 = getelementptr i32*, i32** %arr_pitch967, i32 0
  %malloccall969 = tail call i8* @malloc(i32 mul (i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 3))
  %array970 = bitcast i8* %malloccall969 to i32*
  %prefield_elem971 = getelementptr i32, i32* %array970, i32 0
  store i32 -1, i32* %prefield_elem971
  %scaledegreer_elem972 = getelementptr i32, i32* %array970, i32 1
  store i32 6, i32* %scaledegreer_elem972
  %postfield_elem973 = getelementptr i32, i32* %array970, i32 2
  store i32 0, i32* %postfield_elem973
  store i32* %array970, i32** %pitch_pointer_elem968
  %struct_c_pointer974 = getelementptr inbounds %chord_struct, %chord_struct* %chord_struct964, i32 0, i32 1
  store i32** %arr_pitch967, i32*** %struct_c_pointer974
  %actual_chord_struct975 = load %chord_struct, %chord_struct* %chord_struct964
  store %chord_struct %actual_chord_struct975, %chord_struct* %pointer_chord_elem_list962
  %pointer_chord_elem_list976 = getelementptr %chord_struct, %chord_struct* %chord_pointer_array709, i32 19
  %malloccall977 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct978 = bitcast i8* %malloccall977 to
%chord_struct*
  %length979 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct978, i32 0, i32 0
  store i32 1, i32* %length979
  %malloccall980 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch981 = bitcast i8* %malloccall980 to i32**
  %pitch_pointer_elem982 = getelementptr i32*, i32**
%arr_pitch981, i32 0
  %malloccall983 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array984 = bitcast i8* %malloccall983 to i32*
  %prefield_elem985 = getelementptr i32, i32* %array984, i32
0
  store i32 -1, i32* %prefield_elem985
  %scaledegreer_elem986 = getelementptr i32, i32* %array984,
i32 1
  store i32 5, i32* %scaledegreer_elem986
  %postfield_elem987 = getelementptr i32, i32* %array984, i32
2
  store i32 0, i32* %postfield_elem987
  store i32* %array984, i32** %pitch_pointer_elem982
  %struct_c_pointer988 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct978, i32 0, i32 1
  store i32** %arr_pitch981, i32*** %struct_c_pointer988
  %actual_chord_struct989 = load %chord_struct,
%chord_struct* %chord_struct978
  store %chord_struct %actual_chord_struct989, %chord_struct*
%pointer_chord_elem_list976
  %pointer_chord_elem_list990 = getelementptr %chord_struct,
%chord_struct* %chord_pointer_array709, i32 20
  %malloccall991 = tail call i8* @malloc(i32 ptrtoint
(%chord_struct* getelementptr (%chord_struct, %chord_struct*
null, i32 1) to i32))
  %chord_struct992 = bitcast i8* %malloccall991 to
%chord_struct*
  %length993 = getelementptr inbounds %chord_struct,
%chord_struct* %chord_struct992, i32 0, i32 0
  store i32 1, i32* %length993
  %malloccall994 = tail call i8* @malloc(i32 ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32))
  %arr_pitch995 = bitcast i8* %malloccall994 to i32**
  %pitch_pointer_elem996 = getelementptr i32*, i32**
%arr_pitch995, i32 0
  %malloccall997 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32),
i32 3))
  %array998 = bitcast i8* %malloccall997 to i32*
  %prefield_elem999 = getelementptr i32, i32* %array998, i32
0
  store i32 0, i32* %prefield_elem999
  %scaledegreer_elem1000 = getelementptr i32, i32* %array998,
i32 1
  store i32 3, i32* %scaledegreer_elem1000
  %postfield_elem1001 = getelementptr i32, i32* %array998,
i32 2
  store i32 0, i32* %postfield_elem1001
  store i32* %array998, i32** %pitch_pointer_elem996
  %struct_c_pointer1002 = getelementptr inbounds
%chord_struct, %chord_struct* %chord_struct992, i32 0, i32 1
  store i32** %arr_pitch995, i32*** %struct_c_pointer1002
  %actual_chord_struct1003 = load %chord_struct,
%chord_struct* %chord_struct992
  store %chord_struct %actual_chord_struct1003,
%chord_struct* %pointer_chord_elem_list990
  %struct_cl_pointer1004 = getelementptr inbounds
%chordlist_struct, %chordlist_struct* %cl_struct706, i32 0,
i32 1
  store %chord_struct* %chord_pointer_array709,
%chord_struct** %struct_cl_pointer1004
  %arp = alloca %chordlist_struct*
  store %chordlist_struct* %cl_struct706, %chordlist_struct**
%arp
  %array_struct1005 = alloca %list_struct_f
  %length1006 = getelementptr inbounds %list_struct_f,
%list_struct_f* %array_struct1005, i32 0, i32 0
  store i32 21, i32* %length1006
  %array1007 = alloca double, i32 21
  %elem1008 = getelementptr double, double* %array1007, i32 0
  store double 2.500000e-01, double* %elem1008
  %elem1009 = getelementptr double, double* %array1007, i32 1
  store double 2.500000e-01, double* %elem1009
  %elem1010 = getelementptr double, double* %array1007, i32 2
  store double 2.500000e-01, double* %elem1010
  %elem1011 = getelementptr double, double* %array1007, i32 3
  store double 2.500000e-01, double* %elem1011
  %elem1012 = getelementptr double, double* %array1007, i32 4
  store double 2.500000e-01, double* %elem1012
  %elem1013 = getelementptr double, double* %array1007, i32 5
  store double 2.500000e-01, double* %elem1013
  %elem1014 = getelementptr double, double* %array1007, i32 6
  store double 2.500000e-01, double* %elem1014
  %elem1015 = getelementptr double, double* %array1007, i32 7
  store double 2.500000e-01, double* %elem1015
  %elem1016 = getelementptr double, double* %array1007, i32 8
  store double 2.500000e-01, double* %elem1016
  %elem1017 = getelementptr double, double* %array1007, i32 9
  store double 2.500000e-01, double* %elem1017
  %elem1018 = getelementptr double, double* %array1007, i32 10
  store double 2.500000e-01, double* %elem1018
  %elem1019 = getelementptr double, double* %array1007, i32 11
  store double 2.500000e-01, double* %elem1019
  %elem1020 = getelementptr double, double* %array1007, i32 12
  store double 2.500000e-01, double* %elem1020
  %elem1021 = getelementptr double, double* %array1007, i32 13
  store double 2.500000e-01, double* %elem1021
  %elem1022 = getelementptr double, double* %array1007, i32 14
  store double 2.500000e-01, double* %elem1022
  %elem1023 = getelementptr double, double* %array1007, i32 15
  store double 2.500000e-01, double* %elem1023
  %elem1024 = getelementptr double, double* %array1007, i32 16
  store double 2.500000e-01, double* %elem1024
  %elem1025 = getelementptr double, double* %array1007, i32 17
  store double 2.500000e-01, double* %elem1025
  %elem1026 = getelementptr double, double* %array1007, i32 18
  store double 2.500000e-01, double* %elem1026
  %elem1027 = getelementptr double, double* %array1007, i32 19
  store double 2.500000e-01, double* %elem1027
  %elem1028 = getelementptr double, double* %array1007, i32 20
  store double 1.250000e+00, double* %elem1028
  %actual_list1029 = getelementptr inbounds %list_struct_f, %list_struct_f* %array_struct1005, i32 0, i32 1
  store double* %array1007, double** %actual_list1029
  %r4 = alloca %list_struct_f*
  store %list_struct_f* %array_struct1005, %list_struct_f** %r4
  %theme1030 = load %chordlist_struct*, %chordlist_struct** %theme
  %length1031 = getelementptr inbounds %chordlist_struct, %chordlist_struct* %theme1030, i32 0, i32 0
  %size = load i32, i32* %length1031
  %r11032 = load %list_struct_f*, %list_struct_f** %r1
  %cur_list_ptr = getelementptr inbounds %list_struct_f, %list_struct_f* %r11032, i32 0, i32 1
  %cur_list = load double*, double** %cur_list_ptr
  %minor11033 = load %list_struct*, %list_struct** %minor1
  %cur_list_ptr1034 = getelementptr inbounds %list_struct, %list_struct* %minor11033, i32 0, i32 1
  %cur_list1035 = load i32*, i32** %cur_list_ptr1034
  %length1036 = getelementptr inbounds %list_struct, %list_struct* %minor11033, i32 0, i32 0
  %size1037 = load i32, i32* %length1036
  %mallocsize = mul i32 %size, ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1038 = tail call i8* @malloc(i32 %mallocsize)
  %return_arr = bitcast i8* %malloccall1038 to i32*
  %mallocsize1039 = mul i32 %size, ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1040 = tail call i8* @malloc(i32 %mallocsize1039)
  %return_arr1041 = bitcast i8* %malloccall1040 to i32**
  %mallocsize1042 = mul i32 %size, ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1043 = tail call i8* @malloc(i32
%mallocsize1042)
  %norm_arr = bitcast i8* %malloccall1043 to i32***
  %length1044 = getelementptr inbounds %chordlist_struct,
%chordlist_struct* %theme1030, i32 0, i32 0
  %size1045 = load i32, i32* %length1044
  %cur_list_ptr1046 = getelementptr inbounds
%chordlist_struct, %chordlist_struct* %theme1030, i32 0, i32
1
  %cur_list1047 = load %chord_struct*, %chord_struct**
%cur_list_ptr1046
  %cur_index_ptr = alloca i32
  store i32 0, i32* %cur_index_ptr
  br label %while

while:                                            ; preds =
%while_body, %entry
  %cur_index2 = load i32, i32* %cur_index_ptr
  %pred = icmp ne i32 %size1045, %cur_index2
  br i1 %pred, label %while_body, label %merge

while_body:                                       ; preds =
%while
  %cur_indexplz = load i32, i32* %cur_index_ptr
  %cur_val = getelementptr inbounds %chord_struct,
%chord_struct* %cur_list1047, i32 %cur_indexplz
  %val_idx = load %chord_struct, %chord_struct* %cur_val
  %cur_val1048 = getelementptr inbounds i32**, i32***
%norm_arr, i32 %cur_indexplz
  %stuff = extractvalue %chord_struct %val_idx, 1
  %len = getelementptr inbounds i32, i32* %return_arr, i32
%cur_indexplz
  %oldlen = extractvalue %chord_struct %val_idx, 0
  %len1049 = getelementptr inbounds i32*, i32**
%return_arr1041, i32 %cur_indexplz
  %mallocsize1050 = mul i32 %oldlen, ptrtoint (i32*
getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1051 = tail call i8* @malloc(i32
%mallocsize1050)
  %clear_cl_list_elem = bitcast i8* %malloccall1051 to i32*
  store i32* %clear_cl_list_elem, i32** %len1049
  store i32 %oldlen, i32* %len
  store i32** %stuff, i32*** %cur_val1048
  %cur_index = load i32, i32* %cur_index_ptr
  %new_idx = add i32 %cur_index, 1
  store i32 %new_idx, i32* %cur_index_ptr
  br label %while

merge:                                            ; preds = %while
  %synth-buffer = tail call i8* @malloc(i32 mul (i32 ptrtoint (i8* getelementptr (i8, i8* null, i32 1) to i32), i32 1000))
  %synth = call i32 @synth(i32*** %norm_arr, i32 %size, i32* %return_arr, i32 50, i32* %cur_list1035, i32 %size1037, double* %cur_list, i32** %return_arr1041, i32 1, i8* %synth-buffer)
  %rone = alloca i8*
  store i8* %synth-buffer, i8** %rone
  %counter1053 = load %chordlist_struct*, %chordlist_struct** %counter
  %length1054 = getelementptr inbounds %chordlist_struct, %chordlist_struct* %counter1053, i32 0, i32 0
  %size1055 = load i32, i32* %length1054
  %r31056 = load %list_struct_f*, %list_struct_f** %r3
  %cur_list_ptr1057 = getelementptr inbounds %list_struct_f, %list_struct_f* %r31056, i32 0, i32 1
  %cur_list1058 = load double*, double** %cur_list_ptr1057
  %minor11059 = load %list_struct*, %list_struct** %minor1
  %cur_list_ptr1060 = getelementptr inbounds %list_struct, %list_struct* %minor11059, i32 0, i32 1
  %cur_list1061 = load i32*, i32** %cur_list_ptr1060
  %length1062 = getelementptr inbounds %list_struct, %list_struct* %minor11059, i32 0, i32 0
  %size1063 = load i32, i32* %length1062
  %mallocsize1064 = mul i32 %size1055, ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1065 = tail call i8* @malloc(i32 %mallocsize1064)
  %return_arr1066 = bitcast i8* %malloccall1065 to i32*
  %mallocsize1067 = mul i32 %size1055, ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1068 = tail call i8* @malloc(i32 %mallocsize1067)
  %return_arr1069 = bitcast i8* %malloccall1068 to i32**
  %mallocsize1070 = mul i32 %size1055, ptrtoint (i1** getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1071 = tail call i8* @malloc(i32 %mallocsize1070)
  %norm_arr1072 = bitcast i8* %malloccall1071 to i32***
  %length1073 = getelementptr inbounds %chordlist_struct, %chordlist_struct* %counter1053, i32 0, i32 0
  %size1074 = load i32, i32* %length1073
  %cur_list_ptr1075 = getelementptr inbounds %chordlist_struct, %chordlist_struct* %counter1053, i32 0, i32 1
  %cur_list1076 = load %chord_struct*, %chord_struct** %cur_list_ptr1075
  %cur_index_ptr1077 = alloca i32
  store i32 0, i32* %cur_index_ptr1077
  br label %while1078

while1078:                                        ; preds = %while_body1079, %merge
  %cur_index21093 = load i32, i32* %cur_index_ptr1077
  %pred1094 = icmp ne i32 %size1074, %cur_index21093
  br i1 %pred1094, label %while_body1079, label %merge1095

while_body1079:                                   ; preds = %while1078
  %cur_indexplz1080 = load i32, i32* %cur_index_ptr1077
  %cur_val1081 = getelementptr inbounds %chord_struct, %chord_struct* %cur_list1076, i32 %cur_indexplz1080
  %val_idx1082 = load %chord_struct, %chord_struct* %cur_val1081
  %cur_val1083 = getelementptr inbounds i32**, i32*** %norm_arr1072, i32 %cur_indexplz1080
  %stuff1084 = extractvalue %chord_struct %val_idx1082, 1
  %len1085 = getelementptr inbounds i32, i32* %return_arr1066, i32 %cur_indexplz1080
  %oldlen1086 = extractvalue %chord_struct %val_idx1082, 0
  %len1087 = getelementptr inbounds i32*, i32** %return_arr1069, i32 %cur_indexplz1080
  %mallocsize1088 = mul i32 %oldlen1086, ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1089 = tail call i8* @malloc(i32
%mallocsize1088)
  %clear_cl_list_elem1090 = bitcast i8* %malloccall1089 to
i32*
  store i32* %clear_cl_list_elem1090, i32** %len1087
  store i32 %oldlen1086, i32* %len1085
  store i32** %stuff1084, i32*** %cur_val1083
  %cur_index1091 = load i32, i32* %cur_index_ptr1077
  %new_idx1092 = add i32 %cur_index1091, 1
  store i32 %new_idx1092, i32* %cur_index_ptr1077
  br label %while1078

merge1095:                                        ; preds =
%while1078
  %synth-buffer1097 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i8* getelementptr (i8, i8* null, i32 1) to i32),
i32 1000))
  %synth1098 = call i32 @synth(i32*** %norm_arr1072, i32
%size1055, i32* %return_arr1066, i32 57, i32* %cur_list1061,
i32 %size1063, double* %cur_list1058, i32** %return_arr1069,
i32 1, i8* %synth-buffer1097)
  %rtwo = alloca i8*
  store i8* %synth-buffer1097, i8** %rtwo
  %theme1099 = load %chordlist_struct*, %chordlist_struct**
%theme
  %length1100 = getelementptr inbounds %chordlist_struct,
%chordlist_struct* %theme1099, i32 0, i32 0
  %size1101 = load i32, i32* %length1100
  %r21102 = load %list_struct_f*, %list_struct_f** %r2
  %cur_list_ptr1103 = getelementptr inbounds %list_struct_f,
%list_struct_f* %r21102, i32 0, i32 1
  %cur_list1104 = load double*, double** %cur_list_ptr1103
  %minor11105 = load %list_struct*, %list_struct** %minor1
  %cur_list_ptr1106 = getelementptr inbounds %list_struct,
%list_struct* %minor11105, i32 0, i32 1
  %cur_list1107 = load i32*, i32** %cur_list_ptr1106
  %length1108 = getelementptr inbounds %list_struct,
%list_struct* %minor11105, i32 0, i32 0
  %size1109 = load i32, i32* %length1108
  %mallocsize1110 = mul i32 %size1101, ptrtoint (i32*
getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1111 = tail call i8* @malloc(i32
%mallocsize1110)
```

```
  %return_arr1112 = bitcast i8* %malloccall1111 to i32*
  %mallocsize1113 = mul i32 %size1101, ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1114 = tail call i8* @malloc(i32
%mallocsize1113)
  %return_arr1115 = bitcast i8* %malloccall1114 to i32**
  %mallocsize1116 = mul i32 %size1101, ptrtoint (i1**
getelementptr (i1*, i1** null, i32 1) to i32)
  %malloccall1117 = tail call i8* @malloc(i32
%mallocsize1116)
  %norm_arr1118 = bitcast i8* %malloccall1117 to i32***
  %length1119 = getelementptr inbounds %chordlist_struct,
%chordlist_struct* %theme1099, i32 0, i32 0
  %size1120 = load i32, i32* %length1119
  %cur_list_ptr1121 = getelementptr inbounds
%chordlist_struct, %chordlist_struct* %theme1099, i32 0, i32
1
  %cur_list1122 = load %chord_struct*, %chord_struct**
%cur_list_ptr1121
  %cur_index_ptr1123 = alloca i32
  store i32 0, i32* %cur_index_ptr1123
  br label %while1124

while1124:                                        ; preds =
%while_body1125, %merge1095
  %cur_index21139 = load i32, i32* %cur_index_ptr1123
  %pred1140 = icmp ne i32 %size1120, %cur_index21139
  br i1 %pred1140, label %while_body1125, label %merge1141

while_body1125:                                   ; preds =
%while1124
  %cur_indexplz1126 = load i32, i32* %cur_index_ptr1123
  %cur_val1127 = getelementptr inbounds %chord_struct,
%chord_struct* %cur_list1122, i32 %cur_indexplz1126
  %val_idx1128 = load %chord_struct, %chord_struct*
%cur_val1127
  %cur_val1129 = getelementptr inbounds i32**, i32***
%norm_arr1118, i32 %cur_indexplz1126
  %stuff1130 = extractvalue %chord_struct %val_idx1128, 1
  %len1131 = getelementptr inbounds i32, i32*
%return_arr1112, i32 %cur_indexplz1126
  %oldlen1132 = extractvalue %chord_struct %val_idx1128, 0
  %len1133 = getelementptr inbounds i32*, i32**
%return_arr1115, i32 %cur_indexplz1126
  %mallocsize1134 = mul i32 %oldlen1132, ptrtoint (i32*
getelementptr (i32, i32* null, i32 1) to i32)
  %malloccall1135 = tail call i8* @malloc(i32
%mallocsize1134)
  %clear_cl_list_elem1136 = bitcast i8* %malloccall1135 to
i32*
  store i32* %clear_cl_list_elem1136, i32** %len1133
  store i32 %oldlen1132, i32* %len1131
  store i32** %stuff1130, i32*** %cur_val1129
  %cur_index1137 = load i32, i32* %cur_index_ptr1123
  %new_idx1138 = add i32 %cur_index1137, 1
  store i32 %new_idx1138, i32* %cur_index_ptr1123
  br label %while1124

merge1141:                                        ; preds =
%while1124
  %synth-buffer1143 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i8* getelementptr (i8, i8* null, i32 1) to i32),
i32 1000))
  %synth1144 = call i32 @synth(i32*** %norm_arr1118, i32
%size1101, i32* %return_arr1112, i32 33, i32* %cur_list1107,
i32 %size1109, double* %cur_list1104, i32** %return_arr1115,
i32 2, i8* %synth-buffer1143)
  %lone = alloca i8*
  store i8* %synth-buffer1143, i8** %lone
  %new_string = tail call i8* @malloc(i32 mul (i32 ptrtoint
(i8* getelementptr (i8, i8* null, i32 1) to i32), i32 1000))
  %first = getelementptr inbounds i8, i8* %new_string, i32 0
  store i8 0, i8* %first
  %rone1146 = load i8*, i8** %rone
  %put_first = call i8* @strcat(i8* %new_string, i8*
%rone1146)
  %lone1147 = load i8*, i8** %lone
  %put_first1148 = call i8* @strcat(i8* %new_string, i8*
%lone1147)
  %song = alloca i8*
  store i8* %new_string, i8** %song
  %new_string1150 = tail call i8* @malloc(i32 mul (i32
ptrtoint (i8* getelementptr (i8, i8* null, i32 1) to i32),
i32 1000))
```

```
  %first1151 = getelementptr inbounds i8, i8* %new_string1150, i32 0
  store i8 0, i8* %first1151
  %song1152 = load i8*, i8** %song
  %put_first1153 = call i8* @strcat(i8* %new_string1150, i8* %song1152)
  %rtwo1154 = load i8*, i8** %rtwo
  %put_first1155 = call i8* @strcat(i8* %new_string1150, i8* %rtwo1154)
  %song1 = alloca i8*
  store i8* %new_string1150, i8** %song1
  %song11156 = load i8*, i8** %song1
  %make_midi = call i32 @make_midi(i8* %song11156, i8* getelementptr inbounds ([10 x i8], [10 x i8]* @0, i32 0, i32 0))
  ret i32 0
}

declare i32 @synth(i32***, i32, i32*, i32, i32*, i32, double*, i32**, i32, i8*)

declare i8* @strcat(i8*, i8*)

declare i32 @make_midi(i8*, i8*)

declare noalias i8* @malloc(i32)
```

```
05/11/17 12:02:23 Untitled

y = 6;
def Fun x = x;
z = Fun(y);
Printint(z);
```

```
; ModuleID = 'MusicMike'

@fmt = private unnamed_addr constant [4 x i8] c"%d\0A\00"
@str = private unnamed_addr constant [4 x i8] c"%s\0A\00"
@flt = private unnamed_addr constant [4 x i8] c"%f\0A\00"
@str.1 = private unnamed_addr constant [3 x i8] c"%c\00"
@fmt.2 = private unnamed_addr constant [4 x i8] c"%d \00"
@fmt.3 = private unnamed_addr constant [4 x i8] c"%f \00"

declare i32 @printf(i8*, ...)

define i32 @main() {
entry:
  %y = alloca i32
  store i32 6, i32* %y
  %y1 = load i32, i32* %y
  %Fun = call i32 @Fun(i32 %y1)
  %z = alloca i32
  store i32 %Fun, i32* %z
  %z2 = load i32, i32* %z
  %printf = call i32 (i8*, ...) @printf(i8* getelementptr
inbounds ([4 x i8], [4 x i8]* @fmt, i32 0, i32 0), i32 %z2)
  ret i32 0
}

declare i32 @synth(i32***, i32, i32*, i32, i32*, i32, double*,
i32**, i32, i8*)

declare i8* @strcat(i8*, i8*)

declare i32 @make_midi(i8*, i8*)

define i32 @Fun(i32 %x) {
entry:
  %x1 = alloca i32
  store i32 %x, i32* %x1
  %x2 = load i32, i32* %x1
  ret i32 %x2
}
```

6.2 Test Suite

05/10/17 11:59:52 C:\Users\husam\Downloads\out (1).txt

```
fail-arith-1.mike

a=1+.1;

fail-arith2.mike

1.0+1.0;

fail-array2.mike

arr=[ "c" 2 3 4 ];

fail-array.mike

arr=[1 1. 3 ];

fail-assign.mike

a=c+1;

fail-if1.mike

if true then 5;

fail-if.mike

if 42 then Printint(5) else Printint(3);

fail-illegal-id.mike

b=2;

fail-index.mike

a=[1 2 3 ];
b=a.[ 3. ];

fail-pitch-empty.mike

p:[3 4 -4 ];
```

```

/* pitch literals cannot be negative */

test-1synth1.mike



pitch_list= p:[ 1 2 3 4 3 2 1];
mode=[1 3 5 6 8 10 12];
rhythm_list=r:[ q q q q q q q];
start_note=60;

s = Synth(pitch_list rhythm_list mode start_note 1  );
s1 = Synth(pitch_list rhythm_list mode 63 2  );
s2 = Merge(s s1);
Make_midi(s2 "plzwork.midi");

test-arith1.mike

Printint(4);
Printint(4+4);
Printint(2*8);
Printint(10/2);


test-arith2.mike

Printfloat (2.22);
Printfloat (3.+.2.5);
Printfloat (10.-.2.);
Printfloat (8.*.4.);
Printfloat (7./.2.);



test-array.mike

[1 2 3];

test-assign-array.mike

a = [1 2 3];
```

```

test-assign.mike

a = 5;
Printint (a);

test-assign-print.mike



a = 5; Printint(a);

test-block-return.mike

/* testing whether {4;5;10;} returns "10" as its value */
Printint({4;5;10;});

test-channel-synth.mike

p1=p:[ 1 2 3 4 5];
mode1= [ 1 2 3 4 5];
rlist1=r:[1 1 1 1 1];
start_note1=50;
channel1=0;



test-flat-v.mike

p:[ v4 v4 6b|4#];

test-floatlist.mike

[ 1. 1. 1. 1. ];

test-float.mike

Printfloat(1.2345);

test-func-decl-call.mike


```

```
def Name = {Printint(10); Printstr("hello"); a = 5 + 10; a;};

Printint(Name());


test-func-decl.mike


def Name hello = {Printint(10); Printstr("hello"); a = 5 + 10;
a;};

test-if.mike


if true then Printint(5) else Printint(10);
if false then Printint(5) else Printint(10);

Printint(15);

test-index2.mike

a=[2 3 4 ];
c=a.[0+1];
Printint(c);

test-index-print.mike

a = [1 2 3]; Printint(a.[2]);

test-int-add.mike


Printint(1 + 10);


test-int.mike

Printint(5);


test-map-1.mike

```

```
l=[ 1 2 3 4 ];
def A a = a + 2;
Map( A l);

test-pitch-empty.mike

p:[ ^3#  ^5#  ^8#];

test-printadd.mike

Printint(5 + 5);

test-printFadd.mike

Printfloat(5. +. 5.);

test-print-index2.mike

a=[ 2 3 4 5];
c= a.[0+1];
Printint(c);

test-printint.mike

Printint(5);

test-print-list.mike

l=[ 1 2 3 4 5];
Printlist( l);

test-rdot.mike

r:[ wo   1. 4.5 8o];

test-rhythm-empty.mike

r:[ w 1. 3. h q];

test-rhythm-list-dec.mike

a = r:[q w];
```

```
Printrlist(a);

test-scope.mike

{
    a=50;
    Printint(a);
};
Printint(a);

test-string.mike

Printstr("helloworld");

test-subset.mike

a=[ 2 3 4 ];
c=a.[2];
Printint(c);

test-type.mike

/* assume print is not different words */
a="hello";
Print( a);
b=8;
Print(b);
c='c';
Print(c);
d=[1 2 3];
Print(d);


test-unary.mike

a= -1;
PrintInt a;

fail-pitch-empty.out


test-1synth1.out
```

```

V1 [61]/1.00 [63]/1.00 [65]/1.00 [66]/1.00 [65]/1.00 [63]/1.00
[61]/1.00 V2 [64]/1.00 [66]/1.00 [68]/1.00 [69]/1.00 [68]/1.00
[66]/1.00 [64]/1.00

test-arith1.out

4
8
16
5

test-arith2.out

2.220000
5.500000
8.000000
32.000000
3.500000

test-array.out


test-assign-array.out


test-assign.out

5
test-assign-print.out

5

test-block-return.out

10

test-flat-v.out


test-floatlist.out

```

```

test-float.out

1.234500

test-func-decl-call.out

10
hello
15

test-func-decl.out


test-if.out

5
10
15

test-index2.out

3

test-index-print.out

3
test-int-add.out

11

test-int.out

5

test-map-1.out

4 4 4 4

test-pitch-empty.out


```

```
test-printadd.out

10

test-printFadd.out

10.000000

test-print-index2.out

3

test-printint.out

5

test-print-list.out

1 2 3 4 5

test-rdot.out


test-rhythm-empty.out


test-rhythm-list-dec.out

1.000000 4.000000

test-scope.out

50

test-string.out

helloworld

test-subset.out

4

```

```
test-type.out

hello
8

fail-arith-1.err

Fatal error: exception Failure("Mismatched types")

fail-arith2.err

Fatal error: exception Failure("Mismatched types")

fail-array2.err

Fatal error: exception Failure("Mismatched types")

fail-array.err

Fatal error: exception Failure("Mismatched types")

fail-assign.err

Fatal error: exception Failure("c Not Found")

fail-assign-print.err

Fatal error: exception Failure("a Not Found")

fail-if1.err

Fatal error: exception Parsing.Parse_error

fail-if.err

Fatal error: exception Failure("Mismatched types")

fail-illegal-id.err

Fatal error: exception Parsing.Parse_error

fail-index.err
```

```

Fatal error: exception Parsing.Parse_error

```

6.3 Test Suites

We wrote tests for every time we implemented a new feature. We also wrote integration tests to make sure that our modules worked in conjunction with each other. For each test, we also wrote an expected output file.

6.4 Test Automation

Our test automation script, testall.sh, runs every test and compares it to the expected output for that test. The testing script is included in the Appendix.

7. Lessons Learned

7.1 Team Reflections

7.1.1 Harvey Wu

This was, by far, the largest project of my programming career, and the first one that involved a lot of teamwork. I learned to communicate often with my team, even if not much progress was being made, if just to touch base and keep each other interested in the project. Safe to say, I also got to know the ins-and-outs of Git pretty well.

I had never touched functional programming before this class and I loved the "if it compiles it works" aspect of OCaml. By implementing a type inference algorithm I also learned a lot about what makes OCaml tick.

Our group spent too much time early on arguing about syntax and design choices that seemed relatively trivial down the road. For future groups: decide on something, and stick to it. Unless it breaks :)

7.1.2 Kaitlin Pet

For the last three years, I have had two reach classes at Columbia- ones whose content I found fascinating but seemed extremely challenging. PLT was one of those classes, am Im glad I finally got to take it as a second semester senior. Because I am concentrating in computer science, this was my first upper-level project-based course and the second major project Ive done at Columbia (the first being a genetic engineering team-based composition that had little to do with computer science). Learning OCaml was an overall fun experience, as someone who hasnt taken Fundamentals the LLVM aspect was a lot more complicated. If music grad school doesnt work out Id definitely like to do more with functional programming. I also liked that you need very little prior information coming in; starting the class I felt on the same page as everyone else. Lastly Id like to thank my teammates, Ive head a lot of horror stories and had a really great experience code grinding with these guys. To future teams, I would suggest 1) bonding with your team early on to feel a sense of connection/obligation to each other, and 2) considering including concentrators because we have hella more time on our hands.

7.1.3 Lakshmi Bodapati

I learned a lot about Git and pull requests and how easily git branches can become messy, unorganized and complicated tree of merge conflicts. I also learned how to solve those problems, maybe not in the Git recommended way, but some way of getting a working master branch after merging in 4+ branches of conflicting code. I also learned a lot about dividing work and maximizing efficiency when all of us were working together and trying to knock out chunks of the project during our longer weekly meetings. The trickiest part was dividing up work such that everyone had something to do that wasn't blocked by something someone else had to do and every task was being worked on by someone who had some idea of what was necessary for successful completion. The coolest thing I learned was how to write a context-sensitive scanner. I learned the most OCaml while writing the polymorphic function definitions and call matching in the semant module. I also learned that OCaml is quite frosty and nice. For future teams, start early, own features not modules and don't be afraid to OCaml it up!

7.1.4 Husam Abdul-Kafi

I learned a lot about how coding a big group project with a lot of people with varying levels of time and preparedness. It was interesting to work around everyone's schedule and maximize the usage of our time. I love OCaml, and I have no problems with using it for this project. I did a past project where we compiled to a version of Java IR (I think it was called Jade?). That project didn't use anything like the OCAML LLVM Model in that we had to emit every line of code in the IR representation by hand. It was really interesting to compare the two types of IR representation (Java JVM is stack based) and learn the differences.

Obviously, I'd recommend any future project to have a working version *at least* a week before the final demo so you can spend time optimizing your code and getting edge cases. Don't forget edge cases!!

8. Appendix

```
(* Abstract Syntax Tree and functions for printing it *)

type op = Add | FAdd | Sub | FSub | Mult | FMult | Div | FDiv
| Equal | Neq | Less | Leq | Greater | Geq | And | Or

type preop = Neg | Not | FNeg

type postop = Rhythmdot

type typ =
    TUnit
  | TInt
  | TBool
  | TFloat
  | TString
  | TPitch
  | TChord
  | TType of string
  | TList of typ
  | TFun of typ list * typ

type expr =
    Literal of int
  | FloatLit of float
  | BoolLit of bool
  | ID of string
  | String of string
  | Binop of expr * op * expr
  | Preop of preop * expr
  | Postop of expr * postop
  | Assign of string * expr
  | Call of expr * expr list
  | If of expr * expr * expr
  | Pitch of int * expr * int
  | Chord of expr list
  | Subset of expr * expr
  | List of expr list
  | PList of expr list
  | ChordList of expr list (*PList --> "list of chords"*)
  | RList of expr list
  | Block of expr list
  | Concat of expr * expr
  | Noexpr
  | Fun of string * string list * expr
  | Unit

type aexpr =
    ALiteral of int * typ
  | AFloatLit of float * typ
  | ABoolLit of bool * typ
  | AID of string * typ
  | AString of string * typ
  | ABinop of aexpr * op * aexpr * typ
  | APreop of preop * aexpr * typ
  | APostop of aexpr * postop * typ
  | AAssign of string * aexpr * typ
  | ACall of aexpr * aexpr list * typ
  | AIf of aexpr * aexpr * aexpr * typ
  | ASubset of aexpr * aexpr * typ
  | AList of aexpr list * typ
  | APList of aexpr list * typ
  | APitch of int * aexpr * int * typ
  | AChord of aexpr list * typ
  | AChordList of aexpr list * typ (*PList --> "list of
chords"*)
  | ARList of aexpr list * typ
  | ABlock of aexpr list * typ
  | AConcat of aexpr * aexpr * typ
  | ANoexpr
  | AFun of string * string list * aexpr * typ (* might be
some issue with formals as string list *)
  | AUnit of typ

type program = expr list

type inferred_program = aexpr list

(* Pretty-printing functions *)

let string_of_op = function
    Add -> "+"
  | FAdd -> "+."
  | Sub -> "-"
  | FSub -> "-."
  | Mult -> "*"
  | FMult -> "*."
  | Div -> "/"
  | FDiv -> "/."
  | Equal -> "=="
  | Neq -> "!="
  | Less -> "<"
  | Leq -> "<="
  | Greater -> ">"
  | Geq -> ">="
  | And -> "&&"
  | Or -> "||"


let string_of_preop = function
    Neg -> "-"
  | Not -> "!"
  | FNeg -> "-"
(*| OctaveUp -> "^"
  | OctaveDown -> "v" *)

let string_of_postop = function
(*    Sharp -> "#"
  | Flat -> "b" *)
  | Rhythmdot -> "o"

let rec string_of_expr = function
    Literal(l) -> string_of_int l
  | FloatLit(f) -> string_of_float f
  | BoolLit(true) -> "true"
  | BoolLit(false) -> "false"
  | ChordList(_) -> "Chordlist"
  | ID(s) -> s
  | String(s) -> s
  | Binop(e1, o, e2) ->
      string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^
string_of_expr e2
  | Preop(o, e) -> string_of_preop o ^ string_of_expr e
(*| Postop(e, o) -> string_of_expr e ^ string_of_postop o *)
  | Assign(v, e) -> "Assign(" ^ v ^ " = " ^ (string_of_expr e)
^ ")"
  | Call(f, el) ->
      string_of_expr f ^ "(" ^ String.concat ", " (List.map
string_of_expr el) ^ ")"
  | If(e1, e2, e3) -> "if " ^ string_of_expr e1 ^ " then " ^
string_of_expr e2 ^ " else " ^ string_of_expr e3
  | Subset(s, i) -> string_of_expr s ^ ".[" ^ string_of_expr i
^ "]"
  | List(es) -> "[ " ^ String.concat " " (List.map
string_of_expr es) ^ " ]"

(*  | ChordList(cs) ->
    let string_of_chord ps =
      let string_of_pitch (i1, e, i2) =
        if i1 < 0 && i2 < 0 then
          (String.make (abs i1) 'v') ^ (string_of_expr e) ^
(String.make (abs i2) 'b')
        else
        if i1 < 0 && i2 >= 0 then
          (String.make (abs i1) 'v') ^ (string_of_expr e) ^
(String.make (abs i2) '#')
        else
        if i1 >= 0 && i2 < 0 then
          (String.make (abs i1) '^') ^ (string_of_expr e) ^
(String.make (abs i2) 'b')
        else
          (String.make (abs i1) '^') ^ (string_of_expr e) ^
(String.make (abs i2) '#')
      in
        String.concat "|" (List.map string_of_pitch ps)
    in
    "p:[" ^ String.concat " " (List.map string_of_chord cs) ^
" ]" *)


  | RList(es) -> "r:[ " ^ String.concat " " (List.map
string_of_expr es) ^ " ]"
  | Block(es) -> "{ " ^ String.concat " " (List.map
string_of_expr es) ^ " }"
  | Concat(e1, e2) -> string_of_expr e1 ^ "@" ^ string_of_expr
e2
  | Noexpr -> ""
  | Unit -> "()"
  | Fun(n, args, e) -> "Fun " ^ n ^ String.concat " " args ^ " = " ^ string_of_expr e
  | _ -> "string_of_expr not implemented for your expression yet."

let rec string_of_typ = function
    TInt -> " [int]"
  | TBool -> " [bool]"
  | TFloat -> " [float]"
  | TString -> " [string]"
  | TPitch -> " [pitch]"
  | TUnit -> " [unit]"
  | TType(s) -> " [" ^ s ^ "]"
  | TFun(t1, t2) -> String.concat " " (List.map string_of_typ t1) ^ " ->" ^ string_of_typ t2
  | TList(s) -> string_of_typ s ^ "list"

let rec string_of_aexpr = function
    ALiteral(l,t)             -> string_of_int l ^ string_of_typ t
  | AFloatLit(f,t)            -> string_of_float f ^ string_of_typ t
  | ABoolLit(true, t)         -> "true" ^ string_of_typ t
  | ABoolLit(false, t)        -> "false" ^ string_of_typ t
  | AID(s, t)                 -> s ^ string_of_typ t
  | AString(s, t)             -> s ^ string_of_typ t
  | APitch(i1, ae, i2, t)    ->
    let signs = (i1 >= 0, i2 >= 0) in
    (match signs with
        false, false ->
          (String.make (abs i1) 'v') ^ (string_of_aexpr ae) ^ (String.make (abs i2) 'b')
      | false, true  ->
          (String.make (abs i1) 'v') ^ (string_of_aexpr ae) ^ (String.make (abs i2) '#')
      | true, false  ->
          (String.make (abs i1) '^') ^ (string_of_aexpr ae) ^ (String.make (abs i2) 'b')
      | _ ->
          (String.make (abs i1) '^') ^ (string_of_aexpr ae) ^ (String.make (abs i2) '#'))

  | ABinop(e1, o, e2, t)    -> string_of_aexpr e1 ^ " " ^ string_of_op o ^
                                " " ^ string_of_aexpr e2 ^ string_of_typ t
  | APreop(o, e, t) -> string_of_preop o ^ string_of_aexpr e ^ string_of_typ t
  | APostop(e, o, t) -> string_of_aexpr e ^ string_of_postop o ^ string_of_typ t
  | AAssign(v, e, t) -> "Assign(" ^ v ^ " = " ^ (string_of_aexpr e) ^ ")" ^ string_of_typ t
  | AFun(id, f, e, t) -> "Function:" ^ "\n" ^ id ^ " " ^ String.concat " " f ^ " -> " ^ string_of_aexpr e ^ "\n Type:" ^ string_of_typ t
  | ACall(f, el, t) ->
    "Call:" ^ "[" ^ string_of_aexpr f ^ "]" ^ "(" ^ String.concat ", " (List.map string_of_aexpr el) ^ ")" ^ string_of_typ t
  | AIf(e1, e2, e3, t) -> "if " ^ string_of_aexpr e1 ^ " then " ^ string_of_aexpr
  e2 ^ " else " ^ string_of_aexpr e3 ^ string_of_typ t
  | ASubset(s, i, t) -> string_of_aexpr s ^ ".[" ^ string_of_aexpr i ^ "]" ^ string_of_typ t
  | AList(es, t) -> begin match t with
    | TList(TPitch) -> "CHORD"
    | TList(TList(TPitch)) -> "CHORDLIST"
    | _ -> "[ " ^ String.concat " " (List.map string_of_aexpr es) ^ " ]" ^ string_of_typ t
    end
  | APList(es, t) -> "p:[ " ^ String.concat " " (List.map string_of_aexpr es) ^ " ]" ^ string_of_typ t
  | ABlock(es, t) -> "{ " ^ String.concat " " (List.map string_of_aexpr es) ^ " }" ^ string_of_typ t
  | AConcat(e1, e2, t) -> string_of_aexpr e1 ^ "@" ^ string_of_aexpr e2 ^ string_of_typ t
  | ANoexpr -> ""
  | AUnit(t) -> "()" ^ string_of_typ t
  | _ -> "[string_of_aexpr not implemented.]"

let string_of_program (exprs) =
  "EXPRESSIONS: " ^ String.concat "\n" (List.map string_of_expr exprs) ^ "\n"
```

```

let string_of_inferred (aexprs) =
  "INFERRED EXPRS: " ^ String.concat "\n" (List.map
string_of_aexpr aexprs) ^
  "\n"

```

```
(*
Code generation: translate takes a semantically checked AST and
produces LLVM IR

Detailed documentation on the OCaml LLVM library:

http://llvm.moe/
http://llvm.moe/ocaml/

*)

module L = Llvm
module A = Ast
module I = Infer

module StringMap = Map.Make(String)

let first  (a,_,_) = a;;
let second (_,a,_) = a;;
let third  (_,_,a) = a;;

let main_vars:(string, L.llvalue) Hashtbl.t = Hashtbl.create 100
let function_defs:(string, (L.llvalue * A.aexpr)) Hashtbl.t = Hashtbl.create 100

(* , functions, structs *)
let translate (exprs) =
  let context = L.global_context () in

  let names:(string, L.llvalue) Hashtbl.t = Hashtbl.create 10 in
  let the_module = L.create_module  context "MusicMike"

  and i32_t   = L.i32_type          context      (* integer *)
  and i8_t    = L.i8_type           context      (* char? *)
  and i1_t    = L.i1_type           context      (* boole *)
  and float_t = L.double_type       context      (* float *)
  and void_t  = L.void_type         context in   (* void *)
  let i8p_t   = L.pointer_type i8_t   in         (* char pointer-string*)
  let i32p_t  = L.pointer_type i32_t in          (* int* *)
  let i32pp_t = L.pointer_type i32p_t in         (* int**  *)
  let i32ppp_t= L.pointer_type i32pp_t in        (* int***  *)
  let floatp_t= L.pointer_type float_t in        (* float* *)

  (* int list struct  *)
  let list_t  = L.named_struct_type context "list_struct" in
  L.struct_set_body list_t  [| i32_t ; i32p_t |] true;
  let listp_t = L.pointer_type list_t in

  (* int * list struct *)
  let chord_struct  = L.named_struct_type context "chord_struct" in
  L.struct_set_body chord_struct  [| i32_t ; i32pp_t |] true;
  let chord_structp = L.pointer_type chord_struct in

  (* int ** list struct  *)
  let chordlist_struct  = L.named_struct_type context "chordlist_struct" in
  L.struct_set_body chordlist_struct  [| i32_t ; chord_structp |] true;
  let chordlist_structp = L.pointer_type chordlist_struct in

  (* float list struct   *)
  let list_t_f  = L.named_struct_type context "list_struct_f" in
  L.struct_set_body list_t_f  [| i32_t ; floatp_t |] true;
  let listp_t_f = L.pointer_type list_t_f in

  let ltype_of_typ = function
      A.TInt     -> i32_t
    | A.TBool    -> i1_t
    | A.TList(A.TInt)    -> listp_t
    | A.TList(A.TFloat)  -> listp_t_f
    | A.TList(A.TList(A.TPitch)) -> chordlist_structp
    (* | A.TVoid    -> void_t  *)
    | A.TFloat   -> float_t
    | A.TString  -> i8p_t
    | A.TUnit    -> void_t
    | t -> raise (Failure (A.string_of_typ(t) ^ "Shouldn't be here")) in

  let stype_of_typ = function
    A.TList(A.TInt) -> (i32_t, list_t)
  | A.TList(A.TFloat) -> (float_t, list_t_f)
  | _ -> raise (Failure "No Struct of this type") in


  (* Declare printf(), which the print built-in function will call *)
  let printf_t = L.var_arg_function_type i32_t [| L.pointer_type i8_t |] in
  let printf_func = L.declare_function "printf" printf_t the_module in

  let default_fun = L.define_function "main" (L.function_type (ltype_of_typ A.TInt) [||]) the_module in
  let builder = L.builder_at_end context (L.entry_block default_fun) in

  let int_format_str = L.build_global_stringptr "%d\n" "fmt" builder in
  let str_format = L.build_global_stringptr "%s\n" "str" builder in
  let float_format = L.build_global_stringptr "%f\n" "flt" builder in
  let char_no_line = L.build_global_stringptr "%c" "str" builder in
  let int_no_line = L.build_global_stringptr "%d " "fmt" builder in
  let float_no_line = L.build_global_stringptr "%f " "fmt" builder in

  (* Declare the built-in synth() function *)
  let synth_t = L.function_type i32_t [|i32ppp_t ; i32_t ; i32p_t; i32_t; i32p_t; i32_t; floatp_t; i32pp_t; i32_t; i8p_t |] in
  let synth_func = L.declare_function "synth" synth_t the_module in

  let strcat_t = L.function_type i8p_t [|i8p_t; i8p_t|] in
  let strcat_func = L.declare_function "strcat" strcat_t the_module in

  (*Declare the build-in make_midi() function*)
  let make_midi_t = L.function_type i32_t [|i8p_t; i8p_t|] in
  let make_midi_func = L.declare_function "make_midi" make_midi_t the_module in
```

```

 (* get length of struct *)
 let get_length (struct_obj, sub_builder) = (*
print_endline(L.string_of_lltype (L.type_of struct_obj)); *)
 (* get pointer to length in the struct (at position 0,0) *)
 let pointer = L.build_in_bounds_gep struct_obj [|
L.const_int i32_t 0; L.const_int i32_t 0 |] "length"
sub_builder in
     (* load that pointer to the length *)
     L.build_load pointer "size" sub_builder
 in
 let get_list (struct_obj, sub_builder) =
  (* get pointer to the int* in the struct (at position 0,1)
*)
  let list_pointer = L.build_in_bounds_gep struct_obj [|
L.const_int i32_t 0; L.const_int i32_t 1 |] "cur_list_ptr"
sub_builder in
  (* load that pointer - now act_list is the pointer to the
head of the list *)
  L.build_load list_pointer "cur_list" sub_builder
 in


 (* s_list is llvalue, application is function taking element
of list, index, and builder *)
 let map s_list  application =
  (* get pointer to length in the struct (at position 0,0)
*)
  let pointer = L.build_in_bounds_gep s_list [| L.const_int
i32_t 0; L.const_int i32_t 0 |] "length" builder in
  (* load that pointer to the length *)
  let length = L.build_load pointer "size" builder in
  (* get pointer to the int* in the struct (at position 0,1)
*)
  let list_pointer = L.build_in_bounds_gep s_list [|
L.const_int i32_t 0; L.const_int i32_t 1 |] "cur_list_ptr"
builder in
  (* load that pointer - now act_list is the pointer to the
head of the list *)
  let act_list = L.build_load list_pointer "cur_list"
builder in
  (* allocate a pointer to an int (on the stack) *)
  let cur_index_ptr = L.build_alloca i32_t "cur_index_ptr"
builder in
```

```
    (* store a 0 in that location *)
    let cur_index = L.build_store (L.const_int i32_t 0) cur_index_ptr builder in

            (* we are creating blocks, so we need the function we are currently in *)
            let cur_fun = L.block_parent (L.insertion_block builder) in
            (* create the block that's supposed to have cur_index < length
               "the conditional block" ==> pred_bb *)
            let pred_bb = L.append_block context "while" cur_fun in
              ignore (L.build_br pred_bb builder);

            (* create the block of the body - basically
                printf act_list[cur_index] *)
            let body_bb = L.append_block context "while_body" cur_fun in
              (* body_builder is the builder in the "while body" *)
            let body_builder = L.builder_at_end context body_bb in

            (* DO THE WORK ON THE ACTUAL ELEMENTS OF THE LIST HERE *)
                (* loads the value in cur_index_ptr *)
                let cur_idx_in_body = L.build_load cur_index_ptr "cur_indexplz" body_builder in
                (* get a pointer into the list at the index with the value just loaded *)
                let ptr_to_idx = L.build_in_bounds_gep act_list [| cur_idx_in_body |] "cur_val" body_builder in
                  (* load the value at that pointer (aka value of act_list[cur_index]) *)
                  let val_idx = L.build_load ptr_to_idx "val_idx" body_builder in
               (* apply function onto element*)
              ignore(application  val_idx cur_idx_in_body body_builder);
              (* print_endline("line 169");*)
              (* END WORK HERE *)

              (* loads the value in cur_index_ptr *)
              let cur_index_val = L.build_load cur_index_ptr "cur_index" body_builder in
              (* add 1 to the value *)
              let new_idx = L.build_add cur_index_val (L.const_int i32_t 1) "new_idx" body_builder in
                (* store the new value in the pointer  *)
                ignore(L.build_store new_idx cur_index_ptr body_builder);
                ignore(L.build_br pred_bb body_builder);

            (* the builder at the "check if cur_index < length" *)
            let pred_builder = L.builder_at_end context pred_bb in
            let cur_index_val2 = L.build_load cur_index_ptr "cur_index2" pred_builder in
            let bool_val = L.build_icmp L.Icmp.Ne length cur_index_val2 "pred" pred_builder in

            let merge_bb = L.append_block context "merge" cur_fun in
              ignore(L.build_cond_br bool_val body_bb merge_bb pred_builder);
              L.position_at_end merge_bb builder;
         in

  let rec expr builder = function
      A.ALiteral(i, _) ->  L.const_int i32_t i
    | A.AFloatLit(f, _) -> L.const_float float_t f
    | A.ABoolLit(b, _) -> L.const_int i1_t (if b then 1 else 0)
    | A.ANoexpr -> L.const_int i32_t 0
    | A.AID(s, _) -> L.build_load (try Hashtbl.find main_vars s with Not_found -> raise(Failure(s ^ " Not Found"))) s builder
    | A.AString(s, _) -> L.build_global_stringptr s "" builder
    | A.ABinop (e1, op, e2, _) ->
            let e1' = expr builder e1
    and e2' = expr builder e2 in
            (match op with
          A.Add     -> L.build_add
        | A.Sub     -> L.build_sub
        | A.Mult    -> L.build_mul
        | A.Div     -> L.build_sdiv
        | A.FAdd    -> L.build_fadd
        | A.FSub    -> L.build_fsub
        | A.FMult   -> L.build_fmul
        | A.FDiv    -> L.build_fdiv
        | A.And     -> L.build_and
        | A.Or      -> L.build_or
        | A.Equal   -> L.build_icmp L.Icmp.Eq
        | A.Neq     -> L.build_icmp L.Icmp.Ne
        | A.Less    -> L.build_icmp L.Icmp.Slt
        | A.Leq     -> L.build_icmp L.Icmp.Sle
        | A.Greater -> L.build_icmp L.Icmp.Sgt
        | A.Geq     -> L.build_icmp L.Icmp.Sge
    ) e1' e2' "tmp" builder

   | A.APitch(preop, e, postop, _) ->
        (* allocates single pitch *)
        let arr_pitch_malloc = L.build_array_malloc i32_t (L.const_int i32_t 3) "array" builder in
        (* prefield *)
        let prefield_pointer=L.build_gep arr_pitch_malloc [|(L.const_int i32_t 0)|] "prefield_elem" builder in
        let el'=L.const_int i32_t preop  in
        ignore(L.build_store el' prefield_pointer builder);

        (*scale degree *)
        let sd_pointer=L.build_gep arr_pitch_malloc [|(L.const_int i32_t 1)|] "scaledegreer_elem" builder in
        let el'=expr builder e in
        ignore(L.build_store el' sd_pointer builder);

        (*posfield*)
        let postfield_pointer=L.build_gep arr_pitch_malloc [|(L.const_int i32_t 2)|] "postfield_elem" builder in
        let el'=L.const_int i32_t postop in
        ignore(L.build_store el' postfield_pointer builder);
        arr_pitch_malloc


   | A.AList(es, t) -> ( match t with
       | TList(TList(TPitch)) ->
           (*allocate struct to hold chordlist and length, struct_c {i32_t, struct_b*} *)
           let cl_struct=L.build_malloc chordlist_struct "cl_struct" builder in
           (* builds pointer for length field in struct to hold length of chordlist *)
           let c_len_pointer = L.build_in_bounds_gep cl_struct [| L.const_int i32_t 0; L.const_int i32_t 0 |] "length" builder in
              ignore(L.build_store (L.const_int i32_t (List.length es)) c_len_pointer builder);
           (* malloc's an array of type struct_b {i32_t, i32_t** } *)
           let arr_malloc = L.build_array_malloc chord_struct (L.const_int i32_t (List.length es)) "chord_pointer_array" builder in
                (* makes chord struct- length + content *)
                (* iterates thru es and builds each chord *)

           let iter_thru_chord index chord =
             let cl2c_pointer = L.build_gep arr_malloc [|(L.const_int i32_t index)|] "pointer_chord_elem_list" builder in
           let e' = expr builder chord in
           let e_val = L.build_load e' "actual_chord_struct" builder in
                      ignore(L.build_store e_val  cl2c_pointer builder);
             in
             (* iterates through chords with iter_thru_chord *)
             List.iteri iter_thru_chord es;
           (* make pointer to chord array in s list *)
          let cl_pointer_arr = L.build_in_bounds_gep cl_struct [| L.const_int i32_t 0; L.const_int i32_t 1 |] "struct_cl_pointer" builder in
          (* fill arr_malloc into pointer to chord list struct *)
          ignore(L.build_store arr_malloc cl_pointer_arr builder); cl_struct

       |  TList(TPitch) -> (*A List of Pitches (aka things separated by | ) *)
            (* allocates the chord list *)
            let c_struct=L.build_malloc chord_struct "chord_struct" builder in
              let c_len_pointer = L.build_in_bounds_gep c_struct [| L.const_int i32_t 0; L.const_int i32_t 0 |]
```

```
"length" builder in
                ignore(L.build_store (L.const_int i32_t (List.length es)) c_len_pointer builder);
            let arr_chord_malloc = L.build_array_malloc i32p_t (L.const_int i32_t (List.length es)) "arr_pitch" builder in
            (* ties c_struct to cl_struct  *)
              let deal_with_pitch index el =
              (*assigns a pointer to the pitch *)
              let pitch_pointer = L.build_gep arr_chord_malloc [| (L.const_int i32_t index)|] "pitch_pointer_elem" builder in
            let e' = expr builder el in
            (* let e_val = L.build_load e' "actual_pitch_struct" builder in  *)
            ignore(L.build_store e' pitch_pointer builder);
              in
              (* iterates through pitches with deal_with_pitch *)
              List.iteri deal_with_pitch es;
            let c_pointer_arr = L.build_in_bounds_gep c_struct [| L.const_int i32_t 0; L.const_int i32_t 1 |] "struct_c_pointer" builder in
            ignore(L.build_store arr_chord_malloc c_pointer_arr builder); c_struct
         |  _ ->
          let s_list = L.build_alloca (snd (stype_of_typ t)) "array_struct" builder in
              let pointer = L.build_in_bounds_gep s_list [| L.const_int i32_t 0; L.const_int i32_t 0 |] "length" builder in
                ignore(L.build_store (L.const_int i32_t (List.length es)) pointer builder);
              let arr_alloc = L.build_array_alloca (fst (stype_of_typ t)) (L.const_int i32_t (List.length es)) "array" builder
              in
              let deal_with_element index e =
              let pointer = L.build_gep arr_alloc [| (L.const_int i32_t index)|] "elem" builder in
              let e' = expr builder e in
                ignore(L.build_store e' pointer builder)
                in List.iteri deal_with_element es;
              let pointer_arr = L.build_in_bounds_gep s_list [| L.const_int i32_t 0; L.const_int i32_t 1 |] "actual_list" builder in
```

```
                ignore(L.build_store arr_alloc pointer_arr builder);  s_list
   )


   | A.ASubset(e1, e2, _)  ->
      let s_list = expr builder e1 in
      let index  = expr builder e2 in
      let pointer = L.build_in_bounds_gep s_list [| L.const_int i32_t 0; L.const_int i32_t 0 |] "length" builder in
      let length = L.build_load pointer "size" builder in
      let list_pointer = L.build_in_bounds_gep s_list [| L.const_int i32_t 0; L.const_int i32_t 1 |] "cur_list_ptr" builder in
      let act_list = L.build_load list_pointer "cur_list" builder in
      let pointer_to_element = L.build_gep act_list [| index |] "pointer_to_element" builder in
      L.build_load pointer_to_element "tmp" builder

    | A.ABlock(es, t) -> ( match es with
        e::e1::rest -> ignore(expr builder e); expr builder (A.ABlock(e1::rest, t))
      | [e] -> expr builder e)
    | A.APreop(op, e, _) ->
       let e' = expr builder e in
       (match op with
             A.Neg     -> L.build_neg
           | A.Not     -> L.build_not
       ) e' "tmp" builder
(*
    | A.AMuPreop(op, e, _) ->
    (* given pointer to pitch array, memory operations for adding or subtracting to position 0 of pitch element *)
    (* index is needed so map will accept it *)
    let interior_operation index pitch builder1 =
    let prefield_pointer=L.build_gep pitch [| (L.const_int i32_t 0)|] "prefield_elem" builder1 in
    let cur_prefield = L.build_load prefield_pointer "cur_prefield" builder1 in
    (match op with
      A.AOup ->
        let new_prefield = L.build_add cur_prefield
(L.const_int i32_t 1) builder1

      A.AOdown ->
        let new_prefield = L.build_sub cur_prefield
(L.const_int i32_t 1) builder1

    )  in
    ignore(L.build_store new_prefield prefield_pointer
builder); in
    (* match different things mupreops could be applied to,
there are 3 *)
         (match e with
      |  A.APitch ->
        let e'=expr builder e in
        interior_operation e' builder

      | A.AChord ->
        let e' = expr builder e in
        map (get_list e' builder) interior_operation

      | A.AChordlist ->
        let e' = expr builder e in
    )

*)
    | A.AAssign (s, e, t) -> let e' = expr builder e in
          let var = try Hashtbl.find main_vars s
                    with Not_found ->
                    let local_var = L.build_alloca
(ltype_of_typ t) s builder in
                        Hashtbl.add main_vars s local_var;
local_var in
                ignore (L.build_store e' var builder); e'
(*    | A.ACall (A.AID("Map", _), act, _) ->
    let func = expr builder (List.hd act) in
    let lst = expr builder (List.hd (List.tl act)) in
    let wrapper f=f in
    map lst (wrapper func); L.const_int i32_t 1
*)

    | A.ACall (A.AID("Printint", _), [e], _) ->
       L.build_call printf_func [| int_format_str ; (expr
builder e) |]  "printf" builder
    | A.ACall (A.AID("Printstr", _), [e], _) ->
```

```
       L.build_call printf_func [| str_format; (expr builder e) |] "printf" builder
    | A.ACall (A.AID("Printfloat", _), [e], _) ->
       L.build_call printf_func [| float_format; (expr builder e) |] "printf" builder
    | A.ACall (A.AID("Printlist", _), [e], _) ->
      let printfun value index builder = L.build_call printf_func [|int_no_line ; value |] "printf" builder in
          let s_list= expr builder e in
          map s_list printfun; L.const_int i32_t 1
    | A.ACall(A.AID("Printrlist", _), [e], _) ->
      let printfun value index builder = L.build_call printf_func [|float_no_line ; value |] "printf" builder in
      let s_list= expr builder e in
      map s_list printfun; L.const_int i32_t 1

    | A.ACall(A.AID("Make_midi", _), [e1; e2], _) ->
    L.build_call make_midi_func [| (expr builder e1); (expr builder e2) |] "make_midi" builder

    | A.ACall(A.AID("Merge", _), [e1; e2], _) ->
(*       ignore(L.build_call printf_func [| str_format; (expr builder e1) |] "printf" builder);
      L.build_call printf_func [| str_format; (expr builder e2) |] "printf" builder
*)   let new_str = L.build_array_malloc i8_t (L.const_int i32_t 1000) "new_string" builder in
      let ptr_to_first = L.build_in_bounds_gep new_str [| L.const_int i32_t 0 |] "first" builder in
      ignore(L.build_store (L.const_int i8_t 0) ptr_to_first builder);
      ignore(L.build_call strcat_func [| new_str; (expr builder e1) |] "put_first" builder);
      ignore(L.build_call strcat_func [| new_str; (expr builder e2) |] "put_first" builder);
      new_str

    (* assumed order of acutals: pitchlist, rhythmlist, modelist, start note, channel num *)
    | A.ACall (A.AID("Synth", _), act, _) ->
    (*extract the actuals *)
    let clist = expr builder (List.hd act) in
    let clist_len = get_length (clist, builder) in
    let rlist = expr builder (List.hd (List.tl act)) in
    let act_rlist = get_list(rlist, builder) in
    let modelist = expr builder (List.hd (List.tl (List.tl act))) in
    let act_modelist = get_list(modelist, builder) in
    let mode_len = get_length(modelist, builder) in
    let start_pitch = expr builder (List.hd (List.tl (List.tl (List.tl act)))) in
    let channel = expr builder (List.hd(List.tl(List.tl(List.tl(List.tl act))))) in
    (*build the nessesary structures to pass into c function - plist as non-struct int***, list of chord lengths, return-arr *)

    (*malloced structure that contains lengths of chords *)
    let chord_lengths = L.build_array_malloc i32_t clist_len "return_arr" builder in
    (*malloced structure that normalized pitch array (no octaves or accidnetals) will be built into. This is passed into C synth function *)
      let clear_cl_list = L.build_array_malloc i32p_t clist_len "return_arr" builder in
    (*building non-struct chord : Note that this refers to both the normal builder and the builder inside the while loop (builder1)*)
    let passed_cl_list =L.build_array_malloc i32pp_t clist_len "norm_arr" builder in
        let chord_func value1 index builder1=
        (* for chord_lengths *)
            let pointer_to_ret_elem = L.build_in_bounds_gep passed_cl_list [| index |] "cur_val" builder1 in
            let new_elem_list = L.build_extractvalue value1 1 "stuff" builder1 in
            let chord_len_pointer =  L.build_in_bounds_gep chord_lengths [| index |] "len" builder1 in
            let new_elem_len = L.build_extractvalue value1 0 "oldlen" builder1 in
            let clear_list_pointer = L.build_in_bounds_gep clear_cl_list [| index |] "len" builder1 in
            let new_clear_arr = L.build_array_malloc i32_t new_elem_len "clear_cl_list_elem" builder1 in
            ignore(L.build_store new_clear_arr clear_list_pointer builder1);
            ignore(L.build_store new_elem_len chord_len_pointer builder1);
            ignore(L.build_store new_elem_list
pointer_to_ret_elem builder1);
            in



       map clist (* (get_list(clist, builder)) *) chord_func;



        (* build buffer *)
    let buff = L.build_array_malloc i8_t (L.const_int i32_t
1000) "synth-buffer" builder in
    (* call synth *)
        ignore(L.build_call synth_func [| (* int ***
*)passed_cl_list; (* int  *)clist_len;
        (* int * *)chord_lengths; (* int  *) start_pitch; (*
int *  *)act_modelist;
        (* int  *)mode_len; (* double *  *)act_rlist; (* int
** *)clear_cl_list; (* int *)channel; (* char * *) buff |]
"synth" builder);
    buff



    | A.ACall (A.AID(s, _), act, _) ->
      let (fdef, fdecl) = Hashtbl.find function_defs s  in
      let actuals = List.rev (List.map (expr builder)
(List.rev act)) in
      let result = (match fdecl with
        A.AFun(f, _, _, _) -> f
        | _ -> raise(Failure "second problem with call") ) in
        L.build_call fdef (Array.of_list actuals) result
builder

    | A.AIf(e1, e2, e3, _) ->
        let bool_val = expr builder e1 in
          let cur_fun = L.block_parent (L.insertion_block
builder) in
          let merge_bb = L.append_block context "merge"
cur_fun in

          let then_bb = L.append_block context "then" cur_fun
in
          ignore(expr (L.builder_at_end context then_bb) e2);
ignore(L.build_br merge_bb (L.builder_at_end context
then_bb));

          let else_bb = L.append_block context "else" cur_fun in
          ignore(expr (L.builder_at_end context else_bb) e3); ignore(L.build_br merge_bb (L.builder_at_end context else_bb));

          ignore(L.build_cond_br bool_val then_bb else_bb builder);
          L.position_at_end merge_bb builder;
          L.const_int i32_t 1

    | A.AFun(fid, arg_list, e, A.TFun(arg_types, ret_type)) ->
      let formal_types = Array.of_list (List.map ltype_of_typ arg_types) in
      let ftype = L.function_type (ltype_of_typ ret_type) formal_types in
      let the_function = L.define_function fid ftype the_module in

      Hashtbl.add function_defs fid
          (the_function, A.AFun(fid, arg_list, e, A.TFun(arg_types, ret_type)));
      let builder2 = L.builder_at_end context (L.entry_block the_function) in
      let alloc_local (s, t, p) =
        L.set_value_name s p;
        let local_var = L.build_alloca (ltype_of_typ t) s builder2 in
            ignore(Hashtbl.add main_vars s local_var);
            ignore(L.build_store p local_var builder2)
      in
        let rec iter3 (f, l1, l2, l3) =
        (match (l1, l2, l3) with
        (hd1::rest1, hd2::rest2, hd3::rest3) -> f(hd1, hd2, hd3); ignore(iter3(f, rest1, rest2, rest3))
        | ([], [], []) -> ()
        | _ -> print_endline "ERROR LINE 491";
       ) in
        iter3 (alloc_local, arg_list, arg_types, (Array.to_list((L.params the_function))));
      let ret_val = expr builder2 e in
```

```
          L.build_ret ret_val builder2


      | _ -> L.const_int i32_t 1
    in
      let exprbuilder builder e = ignore(expr builder e);
  builder
    in
      let builder = List.fold_left exprbuilder builder
  (List.rev(exprs))

    in
    ignore (L.build_ret (L.const_int i32_t 0) builder);
    the_module
```

```
open Ast
open Lib

module StringMap = Map.Make(String)
module StringSet = Set.Make(String)
type environment = typ StringMap.t
type constraints = (typ * typ) list

let letter = ref (Char.code 'a');;
let new_type () = let c1 = !letter in
  incr letter; TType(Char.escaped (Char.chr c1))
;;

let kws = ["if"; "then"; "else"; "true"; "false"; "def"]
;;

let keywords =
  List.fold_left (fun set x -> StringSet.add x set)
StringSet.empty kws
;;

let rec annotate_expr exp env : (aexpr * environment) =
  match exp with
  | Unit        -> AUnit(TUnit), env
  | Literal(n)  -> ALiteral(n, TInt), env
  | FloatLit(n) -> AFloatLit(n, TFloat), env
  | BoolLit(n)  -> ABoolLit(n, TBool), env
  | String(n)   -> AString(n, TString), env
  | ID(n)       -> if StringMap.mem n env then
                     AID(n, StringMap.find n env), env
                   else raise(Failure(n ^ " Not Found"))
  | Binop(e1, op, e2) ->
    let ae1, _ = annotate_expr e1 env
    and ae2, _ = annotate_expr e2 env
    and ntyp = new_type () in
    ABinop(ae1, op, ae2, ntyp), env
  | Preop(preop, e) ->
    let ae, _ = annotate_expr e env
    and ntyp = new_type () in
    APreop(preop, ae, ntyp), env
  | Postop(e, postop) ->
```

```
    let ae, _ = annotate_expr e env
    and ntyp = new_type () in
    APostop(ae, postop, ntyp), env
  | Assign(name, e) ->
    if StringMap.mem name env then
      raise (Failure "Reassignment")
    else if StringSet.mem name keywords then
      raise (Failure "Redefining keyword")
      else let ntyp = new_type () in
    let nenv = StringMap.add name ntyp env in
    let ae, _ = annotate_expr e nenv in
    AAssign(name, ae, ntyp), nenv
  | List(e_list) ->
    let ae_list = List.map (fun e -> fst (annotate_expr e
env)) e_list in
    AList(ae_list, TList(new_type ())), env
  | RList(e_list) ->
    let ae_list = List.map (fun e -> fst (annotate_expr e
env)) e_list in
    AList(ae_list, TList(TFloat)), env
  | Pitch(i1, e, i2) ->
    let ae, _ = annotate_expr e env in
    APitch(i1, ae, i2, TPitch), env
  | Block(e_list) ->
    let ae_list, nenv = ListLabels.fold_left ~init: ([], env)
e_list
        ~f: (fun (ae_list, env) e -> let ae, env =
annotate_expr e env in (ae::ae_list, env))
    in ABlock(ae_list, new_type ()), nenv
  | Chord(e_list) ->
    let ae_list = List.map (fun e -> fst (annotate_expr e
env)) e_list in
    AList(ae_list, TList(TPitch)), env
  | ChordList(e_list) ->
    let ae_list = List.map (fun e -> fst (annotate_expr e
env)) e_list in
    AList(ae_list, TList(TList(TPitch))), env
  | Call(func, args) ->
    let a_func, _ = annotate_expr func env in
    let a_args = List.map (fun arg -> fst (annotate_expr arg
env)) args in
    ACall(a_func, a_args, new_type ()), env
  | If(pred, e1, e2) ->
```

```
    let apred, _ = annotate_expr pred env
    and e1, _ = annotate_expr e1 env
    and e2, _ = annotate_expr e2 env in
    AIf(apred, e1, e2, new_type ()), env
  | Fun(name, args, e) ->
    if StringMap.mem name predefined
    then raise (Failure "Cannot redefine stdlib function.");
    let args_t = List.map (fun f -> new_type ()) args
    and ret_t = new_type() in
    let fun_t = TFun(args_t, ret_t) in
      let a_args = List.combine args args_t in
      let nenv = List.fold_left
            (fun e (id, t) ->
              if StringMap.mem id e
              then raise (Failure "Variable already defined")
              else StringMap.add id t e) env a_args
      in
    if StringMap.mem name env then
      raise (Failure "Redefining function")
    else let nenv = StringMap.add name fun_t nenv in
    let ae, _ = annotate_expr e nenv in
    AFun(name, args, ae, fun_t), nenv
  | Subset(var, e) ->
    let avar, _ = annotate_expr var env
    and ae, _ = annotate_expr e env
    and t = new_type() in
    let typ = t in
    ASubset(avar, ae, t), env
  | _ -> AUnit(TUnit), env
;;

let type_of ae =
  match ae with
  | AUnit(t)         -> t
  | ALiteral(_,t)    -> t
  | AFloatLit(_,t)   -> t
  | AString(_,t)     -> t
  | ABoolLit(_,t)    -> t
  | AID(_,t)         -> t
  | ABinop(_,_,_,t)  -> t
  | APreop(_,_,t)    -> t
  | APostop(_,_,t)   -> t
  | AAssign(_,_,t)   -> t
  | ACall(_,_,t)    -> t
  | ABlock(_,t)   -> t
  | AFun(_,_,_,t)   -> t
  | AList(_,t)      -> t
  | AIf(_,_,_,t)    -> t
  | ASubset(_,_,t)  -> t
  | APitch(_,_,_,t) -> t
  | _               -> print_string "[Missed a type in type_of]"; TUnit
;;


let rec collect_expr ae : constraints =
  match ae with
  | ALiteral(_)     -> []
  | ABoolLit(_)     -> []
  | AFloatLit(_)    -> []
  | AString(_)      -> []
  | AUnit(_)        -> []
  | AID(_)          -> []
  | ABinop(ae1, op, ae2, t) ->
    let t1 = type_of ae1
    and t2 = type_of ae2 in
    let con = match op with
      | Add | Sub | Mult | Div -> [(t1, TInt); (t2, TInt); (t, TInt)]
      | FAdd | FSub | FMult | FDiv -> [(t1, TFloat); (t2, TFloat); (t, TFloat)]
      | Neq | Equal | Greater | Less | Geq | Leq -> [(t1, t2); (t, TBool)]
      | And | Or -> [(t1, TBool); (t2, TBool); (t, TBool)]
    in
    (collect_expr ae1) @ (collect_expr ae2) @ con

  | AAssign(_, ae, t) -> (collect_expr ae) @ [(t, type_of ae)]
  | ABlock(ae_list, t) ->
    let ret = List.hd (List.rev ae_list) in
    let ret_t = type_of ret in
    (List.flatten (List.map collect_expr ae_list)) @ [(t, ret_t)]
  | AList(ae_list, t)   ->
    let list_t = match t with
      | TList(s) -> s
      | _ -> raise (Failure "Unreachable state in List literal") in
    let con = List.map (fun aexpr -> (list_t, type_of aexpr)) ae_list in
    (List.flatten (List.map collect_expr ae_list)) @ con
  | APitch(i1, ae, i2, t) -> [(type_of ae, TInt)]
  | AIf(pred, ae1, ae2, t) ->
    let pt = type_of pred and t1 = type_of ae1 and t2 = type_of ae2 in
    let con = [(pt, TBool); (t1, t2); (t, t1)] in
    (collect_expr pred) @ (collect_expr ae1) @ (collect_expr ae2) @ con

  | AFun(_,_,ae,t) -> begin match t with
    | TFun(_,ret_t) -> (collect_expr ae) @ [(type_of ae, ret_t)]
    | _ -> raise (Failure "Unreachable state in Function literal") end

  | ASubset(v, e, typ) ->
    let vt = (match v with
      | AID(_) -> type_of v
      | _ -> raise (Failure "Unreachable state in Subset") ) in
    let s = match vt with
      | TList(t) -> [(t, typ)]
      | TType(t) -> [(vt, TList(typ))]
      | _ -> raise (Failure "Subset can only be applied to lists")
    in
    (collect_expr e) @ [(type_of e, TInt)] @ s


  | ACall(name, args, t) ->
    let fnt = (match name with
      | AID(_) -> type_of name
      | _ -> raise (Failure "Unreachable state in Call") ) in
    let s = match fnt with
      | TFun(args_t, ret_t) ->
        begin
          let l1 = List.length args and l2 = List.length args_t in
          if l1 <> l2
```

```
     then raise (Failure "Mismatched argument count")
     else let args_c = List.map2 (fun ft at -> (ft, type_of at)) args_t args in
     args_c @ [(t, ret_t)]
    end
   | TType(_) -> [(fnt, TFun(List.map type_of args, t))]
   | _ -> print_endline (string_of_typ fnt); raise (Failure "Mismatched type")
  in
  (collect_expr name) @ (List.flatten (List.map collect_expr args)) @ s

 | e -> raise (Failure ("collect_expr can't handle your expr yet" ^ string_of_aexpr e) )
;;

let rec substitute u x t =
 match t with
 | TUnit | TInt | TBool | TFloat | TPitch | TString -> t
 | TType(c) -> if c = x then u else t
 | TFun(t1, t2) -> TFun(List.map (substitute u x) t1, substitute u x t2)
 | TList(t) -> TList(substitute u x t)
;;

let apply subs t =
  List.fold_right (fun (x, u) t -> substitute u x t) subs t
;;

let rec unify constraints =
 match constraints with
 | [] -> []
 | (x, y) :: tl ->
  let t2 = unify tl in
  let t1 = unify_one (apply t2 x) (apply t2 y) in
  t1 @ t2

and unify_one t1 t2 =
 match t1, t2 with
 | TInt, TInt | TBool, TBool | TString, TString
 | TUnit, TUnit | TFloat, TFloat | TPitch, TPitch -> []
 | TType(x), z | z, TType(x) -> [(x, z)] (* Not completely correct *)
```

```
  | TList(t1), TList(t2) -> unify_one t1 t2
  | TFun(u, v), TFun(x, y) ->
    let l1 = List.length u and l2 = List.length x in
    if l1 = l2 then unify ((List.combine u x) @ [(v, y)])  (*
Double check if
         args are correct *)
    else raise (Failure "Mismatched Argument Count")
  | _ -> raise (Failure "Mismatched types")
;;

let rec apply_expr subs ae =
  match ae with
  | AUnit(t)                   -> AUnit(apply subs t)
  | ALiteral(value, t)         -> ALiteral(value, apply subs t)
  | AFloatLit(value, t)        -> AFloatLit(value, apply subs t)
  | ABoolLit(value, t)         -> ABoolLit(value, apply subs t)
  | AString(value, t)          -> AString(value, apply subs t)
  | ABinop(ae1, op, ae2, t)  ->
      ABinop(apply_expr subs ae1, op, apply_expr subs ae2,
apply subs t)
  | AID(name, t)               -> AID(name, apply subs t)
  | APitch(a, ae, b, t)        ->
     APitch(a, apply_expr subs ae, b, apply subs t)
  | AAssign(name, ae, t)       ->
      AAssign(name, apply_expr subs ae, apply subs t)
  | AList(ae_list, t)          ->
      AList(List.map (apply_expr subs) ae_list, apply subs t)
  | AFun(name, frmls, ae, t) ->
      AFun(name, frmls, apply_expr subs ae, apply subs t)
  | AIf(pred, ae1, ae2, t)     ->
      AIf(apply_expr subs pred, apply_expr subs ae1,
          apply_expr subs ae2, apply subs t)
  | ACall(fname, args, t)      ->
      ACall(apply_expr subs fname,
            List.map (apply_expr subs) args, apply subs t)
  | ABlock(ae_list, t)         ->
      ABlock(List.map (apply_expr subs) ae_list, apply subs t)
  | ASubset(var, i, t)         ->
      ASubset(apply_expr subs var, apply_expr subs i, apply
subs t)
  | e -> raise (Failure ("No apply_expr for AEXPR:" ^
string_of_aexpr e))
;;
```

```

let infer expr env flag =
  let aexpr, nenv = annotate_expr expr env in
  let constraints =
    if flag then
      print_endline ("AEXPR: " ^ string_of_aexpr aexpr);
    collect_expr aexpr in
  let subs =
    List.iter (fun (a,b) ->
      if flag then
        print_endline
      ("CONSTRAINTS: " ^ string_of_typ a ^ " "  ^
string_of_typ b)) constraints;
      unify constraints in
  let inferred_expr =
      List.iter (fun (a,b) -> if flag then
          print_endline ("SUBS: " ^ a ^ " "  ^ string_of_typ
b)) subs;
        apply_expr subs aexpr in
        if flag then
        print_endline("FINAL: " ^ string_of_aexpr
inferred_expr);
  inferred_expr, nenv
;;

let typecheck program flag : (aexpr list) =
  let env = Lib.predefined in
  let inferred_program, _ = ListLabels.fold_left (List.rev
program)

  ~init: ([], env)

  ~f: (
       fun (acc, env) expr ->
        let inferred_expr, env = infer expr env flag in
        let inferred_expr, env = match inferred_expr with
          | AAssign(name, _, t) ->
            let env = StringMap.add name t env in
            inferred_expr, env
          | AFun(name, _, _, t) ->
            let env = StringMap.add name t env in
            inferred_expr, env
          | _ -> inferred_expr, env in
          (inferred_expr :: acc, env)
        )

    in (* List.rev *) inferred_program
;;

```

```
open Ast

module StringMap = Map.Make(String)

let stdlib = [
    ("Printint", TFun([TInt], TString));
    ("Printstr", TFun([TString], TString));
    ("Printfloat", TFun([TFloat], TString));
    ("Printlist", TFun([TList(TInt)], TString));
    ("Printrlist", TFun([TList(TFloat)], TString));
    ("Synth", TFun( [TList(TList(TPitch)); TList(TFloat);
TList(TInt); TInt; TInt], TString));
    ("Make_midi", TFun( [TString; TString], TUnit));
    ("Merge", TFun( [TString; TString] , TString));
];;

let predefined =
  List.fold_left (fun env (id, t) -> StringMap.add id t env)
  StringMap.empty stdlib
;;
```

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```c
#include <unistd.h>

int make_midi(char * buffer, char * name){
  execl("./testCFugueLib", "./testCFugueLib", buffer, name,
(char *)0);
  return 0;
}
```

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```
# Make sure ocamlbuild can find opam-managed packages: first run
#
# eval `opam config env`

# Easiest way to build: using ocamlbuild, which in turn uses ocamlfind

all : musicmike.native synth.o make_midi.o

musicmike.native :
	ocamlbuild -ocamlyacc "ocamlyacc -v" -use-ocamlfind -pkgs llvm,llvm.analysis -cflags -w,+a-4 \
		musicmike.native

# "make clean" removes all generated files

.PHONY : clean
clean :
	ocamlbuild -no-log -clean
	rm -rf testall.log *.diff musicmike scanner.ml parser.ml parser.mli
	rm -rf synth make_midi
	rm -rf *.cmx *.cmi *.cmo *.cmx *.o *.s *.ll *.out *.exe *.output

parser:
	ocamlyacc -v parser.mly

scanner:
	ocamllex scanner.mll

frontend:
	ocamllex scanner.mll
	ocamlc -c ast.ml
	ocamlyacc -v parser.mly
	ocamlc -c parser.mli
	ocamlc -c lib.ml


# More detailed: build using ocamlc/ocamlopt + ocamlfind to
```

```
locate LLVM

OBJS = ast.cmx codegen.cmx infer.cmx lib.cmx parser.cmx
scanner.cmx semant.cmx musicmike.cmx

musicmike : $(OBJS)
    ocamlfind ocamlopt -linkpkg -package llvm -package
llvm.analysis $(OBJS) -o musicmike

scanner.ml : scanner.mll
    ocamllex scanner.mll

parser.ml parser.mli : parser.mly
    ocamlyacc parser.mly

%.cmo : %.ml
    ocamlc -c $<

%.cmi : %.mli
    ocamlc -c $<

%.cmx : %.ml
    ocamlfind ocamlopt -c -package llvm $<

# Synth from microC
synth : synth.c
            cc -o synth -DBUILD_TEST synth.c
make_midi : make_midi.c
            cc -o make_midi -DBUILD_TEST make_midi.c
### Generated by "ocamldep *.ml *.mli" after building
scanner.ml and parser.ml
ast.cmo :
ast.cmx :
codegen.cmo : ast.cmo
codegen.cmx : ast.cmx
musicmike.cmo : semant.cmo scanner.cmo parser.cmi codegen.cmo
ast.cmo infer.cmo
musicmike.cmx : semant.cmx scanner.cmx parser.cmx codegen.cmx
ast.cmx infer.cmx
parser.cmo : ast.cmo parser.cmi
parser.cmx : ast.cmx parser.cmi
scanner.cmo : parser.cmi
scanner.cmx : parser.cmx
```

```
semant.cmo : ast.cmo
semant.cmx : ast.cmx
infer.cmo : ast.cmo lib.cmo
infer.cmx : ast.cmx lib.cmx
lib.cmo: ast.cmo
lib.cmx: ast.cmx
parser.cmi : ast.cmo

```

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```
(* Top-level of the MusicMike compiler: scan & parse the input,
   check the resulting AST, generate LLVM IR, and dump the
module *)

type action = Ast | LLVM_IR | Sast | Compile | Semant

let _ =
  let action = if Array.length Sys.argv > 1 then
    List.assoc Sys.argv.(1) [ ("-t", Sast);(* Print the AST
only *)
                  ("-a", Ast);
                  ("-l", LLVM_IR);  (* Generate LLVM, don't
check *)
                  ("-c", Compile);
                  ("-s", Semant)] (* Generate, check LLVM IR *)
  else Compile in
  let lexbuf = Lexing.from_channel stdin in
  let ast = Parser.program Scanner.next_token lexbuf in
  let sast =
  match action with
  | Ast -> []
  | Sast -> Infer.typecheck ast true
  | Semant -> Semant.check (Infer.typecheck ast true)
  | _ -> Semant.check (Infer.typecheck ast false) in

  match action with
  | Ast -> print_string (Ast.string_of_program ast)
  | Sast -> print_string (Ast.string_of_inferred sast)
  | LLVM_IR -> print_string (Llvm.string_of_llmodule
(Codegen.translate sast))
  | Semant -> print_string  ("SEMANT DEBUGGING :" ^
Ast.string_of_inferred (List.rev sast))
  | Compile -> let m = Codegen.translate sast in
    Llvm_analysis.assert_valid_module m;
    print_string (Llvm.string_of_llmodule m)
```

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```
%{
    open Ast
%}

%token SEMI LPAREN RPAREN LBRACE RBRACE COMMA LBRACKET
RBRACKET PLBRACKET RLBRACKET LTUPLE RTUPLE
%token OUP ODOWN FLAT OCTOTHORPE RHYTHMDOT DOTLBRACKET BAR

%token PLUS MINUS TIMES DIVIDE ASSIGN NOT FPLUS FMINUS FTIMES
FDIVIDE CONCAT
%token EQ NEQ LT LEQ GT GEQ TRUE FALSE AND OR
%token IF THEN ELSE WHILE INT BOOL VOID
%token TYP DEF FOR
%token <int> LITERAL
%token <float> FLITERAL
%token <string> STRING
%token <string> ID FID
%token EOF

%right ASSIGN
%right call
%right IF
%left OR
%left AND
%left EQ NEQ
%nonassoc LT GT LEQ GEQ
%left PLUS MINUS FPLUS FMINUS
%left TIMES DIVIDE FTIMES FDIVIDE
%left OUP ODOWN FLAT OCTOTHORPE RHYTHMDOT
%right RBRACKET
%left LBRACKET
%left CONCAT
%right NOT NEG

%start program
%type <Ast.program> program

%%

/* "A program consists of a list of statements, aka `stmts`"*/

program:

  stmts EOF              { $1 }



/* "stmts is a tuple with the first field being a list of expressions (expr),
the second field being a list of function declarations (fdecl), and the
third field being a list of type declaratiosn (tdecl)" */

stmts:
                       { [] }
  | stmts expr  SEMI   { $2 :: $1 }


/* "A function declaration `fdecl` consists of
    a keyword 'Def'

    a Function Identifier `FID` - string w/ first letter capitalized
    a list of formals `formals_list`
    a body which consists of an `expr` expression "*/

fdecl:
    DEF FID formals_list ASSIGN expr { Fun($2, List.rev($3), $5) }

/* "expressions always return a value and consists of:
    literals-basic types
    binop-binary operator
    unop-unary operators
    primaries-miscelaneous pool (list type, assignment, etc. "*/

expr:
    literals { $1 }
  | binop    { $1 }
  | unop     { $1 }
  | primaries { $1 }
  | fdecl    { $1 }
  | LPAREN expr RPAREN { $2 }

literals:
    LITERAL         { Literal($1) }
  | FLITERAL        { FloatLit($1) }
  | TRUE            { BoolLit(true) }
  | FALSE           { BoolLit(false) }
  | LPAREN RPAREN   { Unit }
  | ID              { ID($1) }
  | STRING          { String($1) }



binop:
  | expr PLUS    expr { Binop($1, Add,   $3) }
  | expr MINUS   expr { Binop($1, Sub,   $3) }
  | expr TIMES   expr { Binop($1, Mult,  $3) }
  | expr DIVIDE  expr { Binop($1, Div,   $3) }
  | expr FPLUS   expr { Binop($1, FAdd,  $3) }
  | expr FMINUS  expr { Binop($1, FSub,  $3) }
  | expr FTIMES  expr { Binop($1, FMult, $3) }
  | expr FDIVIDE expr { Binop($1, FDiv,  $3) }
  | expr EQ      expr { Binop($1, Equal, $3) }
  | expr NEQ     expr { Binop($1, Neq,   $3) }
  | expr LT      expr { Binop($1, Less,  $3) }
  | expr LEQ     expr { Binop($1, Leq,   $3) }
  | expr GT      expr { Binop($1, Greater, $3) }
  | expr GEQ     expr { Binop($1, Geq,   $3) }
  | expr AND     expr { Binop($1, And,   $3) }
  | expr OR      expr { Binop($1, Or,    $3) }

unop:
/*| MINUS expr %prec NEG { Preop(Neg, $2) }  */
  | NOT expr              { Preop(Not, $2) }



primaries:
    /* "Block of expressions" */

    LBRACE semi_list RBRACE { Block($2) }
    /* "Calling a function "*/
  | FID LPAREN actuals_list RPAREN  { Call(ID($1),
List.rev($3)) }
    /* "Assigning a value to an variable"*/
  | assign          { $1 }
    /* "list of expressions of same type (enforced in
semant.ml)" */
  | LBRACKET expr_list RBRACKET { List(List.rev($2)) }
    /* "list of chords" */
  | PLBRACKET pxpr_list RBRACKET { ChordList(List.rev($2)) }
       /*"list of rhythms"*/
  | RLBRACKET expr_list RBRACKET { RList(List.rev($2)) }
       /* "tuple of expressions with different types (enforced
in semant.ml)" */
/*  | LTUPLE expr_list RTUPLE      { Tuple($2) }*/
    /* "concatanating 2 lists (enforced in semant.ml)" */
  | expr CONCAT expr { Concat($1, $3) }
    /* "If, then else "*/
  | IF expr THEN expr ELSE expr
      %prec IF
     { If($2, $4, $6) }
    /* "getting an element from a list/tuple/pitchlist" */
  | ID DOTLBRACKET expr RBRACKET { Subset(ID($1), $3) }



        /* "Assigning a value to an variable"*/
assign:
    ID ASSIGN expr         { Assign($1, $3) }

/*" List of assingments (a=b) used in type declaration " */

assign_list:

    assign                 { [$1] }
  | assign_list assign     { $2 :: $1 }


/* "List of whitespace separated expressions used in
    -Lists
    -Tuples" */
expr_list:
   /*nothing*/             { [] }
  | expr_list expr         { $2 :: $1 }



/* "List of semicolon separated expressions used in block" */

semi_list:
    expr SEMI                 { [$1] }
  | semi_list expr SEMI     { $2 :: $1 }



/* "List of formal arguments used in function declaration"
*/

formals_list:
    /*nothing*/                        { [] }
  | formals_list ID         { $2 :: $1 }


/* "List of actual arguments used in function calls" */

actuals_list:
    /*nothing*/                      { [] }
  | actuals_list expr       { $2 :: $1 }


/* "List of whitespace separated chords(simultaneous pitches)
used in Plist (pitch list) "*/

pxpr_list:
    chord                   { [Chord($1)] }
  | pxpr_list chord         { Chord($2) :: $1 }


/* "List of simulateous pitches" */


chord:
    pitch                   { [$1] }
  | chord BAR pitch         { $3 :: $1 }


/*p:[3|5|6  3  ^^3#|9bb]*/


/* "Tuple consisting of 3 fields:
    prefield-a list of ints representing '^' and 'v' as  '1'
and '-1'
      an int representing scale degree inputed by user
      postfield-a list of ints representing '#' and 'b' as '1'
```

```
and '-1' "*/

pitch:
    prefield expr postfield { Pitch($1, $2, $3) }


/*"a list of ints representing '^' and 'v' as  '1' and '-1'
respectively" */

prefield:
/* nothing */               { 0 }
  | prefield OUP            { $1+1 }
  | prefield ODOWN          { $1-1 }


/* "a list of ints representing '#' and 'b' as '1' and '-1'
"*/

postfield:
/*nothing*/                 { 0 }
  | postfield OCTOTHORPE    { $1+1 }
  | postfield FLAT          { $1-1 }

```

```
(* Semantic checking for the MicroC compiler *)

open Ast
open Infer
module StringMap = Map.Make(String)

(* Hack for polymorphism compilation: take each polymorphic
function and check when it is called.
* Create a new Function Aexpr for each time it is called, with
the specific type of the actuals. *)

let check (aexprs: aexpr list) =
  let is_poly ae = match ae with
    | AFun(_,_,_,TFun(f_t, r_t)) ->
        let poly t = match t with
          | TType(_) -> true
          | _ -> false
        in
        List.exists poly f_t
    | _ -> false
  in
  let poly = List.filter is_poly aexprs in
  let getname ae = match ae with
    | AFun(fn,_,_,_) -> fn
    | _ -> raise (Failure "What the hell you doin")
  in
  let poly_fnames = List.map getname poly in
  let rec is_call ae = match ae with
    | [] -> []
    | AAssign(_,ie,_)::rest -> (match ie with
        | ACall(AID(fn,t), args, rt) -> let name = fn in
        if List.mem name poly_fnames then
          ACall(AID(fn,t),args, rt)::(is_call rest)
        else (is_call rest)
        | _ -> is_call rest)
    | ACall(AID(fn,t), args, rt)::rest -> let name = fn in
        if List.mem name poly_fnames then
          ACall(AID(fn,t),args, rt)::(is_call rest)
        else (is_call rest)
    | x::rest -> is_call rest
  in
  let polycalls = is_call aexprs in
  let rec matching x lst =
      match lst
      with [] -> []
    | ACall(AID(x,t), a, b)::rest -> ACall(AID(x,t), a, b)::
(matching x rest)
    | y::rest -> matching x rest
    in
  let poly t = match t with
            | TType(_) -> true
            | _ -> false
          in
  let rec iterAexprs alist =
    match alist with
    [] -> []
    | AFun(fn, a, b, TFun(ts, ret_t))::rest ->
    if List.exists poly ts then
       let callmatches = matching fn polycalls in
        let typelist cm =
          (match cm with
          ACall(_, c, _) -> List.map Infer.type_of c
          | _ -> [] )
        in
        let calltofun cm1 = AFun(fn, a, b, TFun(typelist cm1,
Infer.type_of cm1)) in
         (List.map calltofun callmatches)@(iterAexprs rest)
    else
      AFun(fn, a, b, TFun(ts, ret_t))::(iterAexprs rest)
    | w::rest -> w::(iterAexprs rest)
  in iterAexprs aexprs;;

```

```c
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include <string.h>
#include <unistd.h>
#include <errno.h>


int ***fold_lists ( int ***chord_list, int cl_length, int chord_lengths[],
int start_pitch, int *modelist, int mode_length){
//fprintf(stderr,"%s\n", "entering chord list");
//map the mode to absolute pitches (0 corresponds to first scale degree)

int i=0;
while (i<mode_length){
        modelist[i]=modelist[i]+start_pitch;
        //fprintf(stderr,"%s %d\n", "new mode value = ", modelist[i]);
    i+=1;
        }
//runs off assumption that malloced chunks are  not contiguous
int j=0;
while (j<cl_length){
    int ** chord= chord_list[j];
    int i=0;
    //fprintf(stderr,"%s %d\n", "chord number", j);
        while (i<chord_lengths[j]){
        //fprintf(stderr,"%s %d\n", "into while loop", i);
        //fprintf(stderr,"%p\n", chord);
        int * pitch= chord[i];
        //fprintf(stderr,"%s %d\n", "pitch number", i);
        //fprintf(stderr,"%s\n", "int *pitch=chord[i];");
        //new pitch to be added
        int transformed_pitch;
        int p=pitch[1];
        if (p==0){
            transformed_pitch=0;
        }
        else{
            int oup=(p-1)/mode_length;
            if (oup>0){
            //add 'overflow' to octaveup
            pitch[0]+=oup;
            }
            transformed_pitch=modelist[(p-1)%mode_length];
        }
        pitch[1]=transformed_pitch;

        i++;
        }
    j++;
    }
//fprintf(stderr,"%s\n", "after while loop");
return chord_list;
}

//takes normalized chord list and spits out list with actual pitches
int ** apply_accidentals (int ***chordlist, int cl_len, int *chord_lengths, int mode_length, int **return_arr, int * mode)
{
        int octave=mode[mode_length-1]-mode[0];

        int j=0;
        while (j<cl_len){
                int ** chord= chordlist[j];
                int i=0;
                while (i<chord_lengths[j]){
                        int * pitch= chord[i];
            if (pitch[1]!=0){
                //add or subtract octaves
                int octave_shift=pitch[0]*octave;
                pitch[1]=pitch[1]+octave_shift;
                //add or subtract accidentals
                pitch[1]=pitch[1]+pitch[2];
            }
            (return_arr[j])[i]=pitch[1];

            i++;
                        }
                j++;
                }


        return return_arr;
}


//string generator, takes rhythm list plus absolute pitch list and turns into strings that can be plopped in Cfugue
//gonna mix in some c++ lets see if it crashes :/
int strgen (char * buff, double * rhythmlist, int ** corrected_chordlist, int cl_len, int * chord_lengths, int channel){
       //first add channel to beginning
    char v[3];
    strcpy(v, "V");
    strcat(buff, v);
    char channel_buff[3];
    snprintf(channel_buff, 3, "%d", channel);
    strcat(buff, channel_buff);
    char space[2];
    strcpy(space, " ");
    strcat(buff, space);
    int j=0;
    while (j<cl_len){
        //take note_len and convert into string
        double note_len= rhythmlist[j];
        //fprintf(stderr, "note_len: %.2f\n", note_len);
        char snote_len[10];
        memset(snote_len, '\0', sizeof(snote_len));
        snprintf(snote_len, 10, "%.2f", note_len);
        //initialize chord
        int * chord= corrected_chordlist[j];
        int i=0;
        while (i<chord_lengths[j]){
            int pitch= chord[i];
            //convert pitch into string
            char pitchstring[3];
            snprintf(pitchstring, 3, "%d", pitch);
            //buffer all the goddamn symbols
            char lbracket[2];
```

```
                strcpy(lbracket, "[");
                char rbracket[3];
                strcpy(rbracket, "]/");
                char plus[2];
                strcpy(plus, "+ ");
                char space[2];
                strcpy(space, " ");
                char rest[3];
                strcpy(rest, "R/");
                //make acutal pitchstring
                if (pitch==0){
                    strcat(buff, rest);
                }
                else{
                    strcat(buff, lbracket);
                    strcat(buff, pitchstring);
                    strcat(buff, rbracket);
                }
                            strcat(buff, snote_len);

                if (i<chord_lengths[j]-1){
                    strcat(buff, plus);
                    }
                else{
                    strcat(buff, space);
                    }
                i++;
                }
            j++;
            }

    return 0;


}



//synth- imitates behavior of main(), compared at end

int synth(int *** chordlist, int len_chordlist, int *
chord_lengths,
```

```c
    int start_pitch, int * modelist, int mode_length, double *rhythmlist,
    int **pure_chord_arr, int channel, char * buff){
    //fprintf(stderr,"%s\n", "in synth");

    int *** new_chordlist = (int ***) malloc(len_chordlist * sizeof(int **));

    int j1=0;
    while (j1<len_chordlist){
        //fprintf(stderr, "%d\n", j1);
        //fprintf(stderr, "%s\n", "LINE 162");
        int ** chord= chordlist[j1]; //old
        int ** new_chord = (int **) malloc(chord_lengths[j1]*sizeof(int *));
        new_chordlist[j1]=new_chord;//stuff in
        int i=0;
        while (i<chord_lengths[j1]){
            //fprintf(stderr, "%s\n", "LINE 167");
            int *pitch= chord[i];//old
            int *new_pitch = (int *) malloc(3*sizeof(int));
            new_chord[i]=new_pitch;
            new_pitch[0] = pitch[0];
            new_pitch[1] = pitch[1];
            new_pitch[2] = pitch[2];
            //fprintf(stderr, "%s\n", "LINE 173");
            //fprintf(stderr, "%s\n", "LINE 175");
            i++;
            }
        j1++;
    }

    int *new_modelist = (int *) malloc(mode_length * sizeof(int *));
    int j2 = 0;
    while(j2 < mode_length) {
        new_modelist[j2] = modelist[j2];
        j2++;
        }

    // int i = 0;
    // while (i<len_chordlist){
```

```
//      int **temp=(int **)malloc(chord_lengths[i]*sizeof(int *));
    //     fprintf(stderr,"%s\n", "fuck pointers");
    //     new_chordlist[i]=temp;
    //     fprintf(stderr,"%s\n", "pointers are cooeilo");
//      int j=0;
    //     while (j<chord_lengths[i]){
    //         fprintf(stderr,"%s %d\n", "r = ", r);
    //         int* temp2=(int *) malloc(3*sizeof(int));
    //         temp[j] = temp2;
    //         // (chordlist[i])[j]=temp2;
    //         int* pitch=(chordlist[i])[j];
    //         pitch[1]=r;
    //         pitch[2]=c;
    //         r++;
    //         j++;
    //     }
    //     i++;
    // }



    // int j=0;
    // while (j<len_chordlist){
    //     int ** chord= chordlist[j];
    //     fprintf(stderr,"%p\n", chord);
    //     int i=0;
    //     while (i<chord_lengths[j]){
    //         int * pitch= chord[i];
    //             fprintf(stderr,"\t%p\n", pitch);
    //             fprintf(stderr,"\t\t%d\n", pitch[0]);
    //         fprintf(stderr,"\t\t%d\n", pitch[1]);
    //         fprintf(stderr,"\t\t%d\n", pitch[2]);

    //         i++;
    //         }
    //     j++;
    //     }
    //modifies chordlist so mode is normalize to absolute value of notes. If range goes above octave, adds to prefield
    int ***new_list = fold_lists(new_chordlist, len_chordlist, chord_lengths, start_pitch, new_modelist, mode_length);
```

```c
    //fprintf(stderr,"%s\n", "AFTER NEW LIST");
    int j=0;
    while (j<len_chordlist){
        int ** chord= new_list[j];
        //fprintf(stderr,"%p\n", chord);
        int i=0;
        while (i<chord_lengths[j]){
            int * pitch= chord[i];
                //fprintf(stderr,"\t%p\n", pitch);
                //fprintf(stderr,"\t\t%d\n", pitch[0]);
            //fprintf(stderr,"\t\t%d\n", pitch[1]);
            //fprintf(stderr,"\t\t%d\n", pitch[2]);

            i++;
            }
        j++;
        }
    //copies new_list into pure_chord_list to incorporate octaves and accidentals (yes, I know a new int ** is redundant but atm just want to see if works
    //fprintf(stderr,"%s\n", "after new_list");
    int **correct_pitches=apply_accidentals(new_list, len_chordlist, chord_lengths, mode_length, pure_chord_arr, new_modelist);
    //fprintf(stderr,"%d\n", chord_lengths[0]);
    //takes rhythm list and turns into string that can be fed into CFugue
        memset(buff, '\0', 900);
        strgen (buff, rhythmlist, correct_pitches, len_chordlist, chord_lengths, channel );
    fprintf(stderr,"buff %s\n", buff);

    return 0;
}





// //tester
   // int main(){

```

```


//      //variablesle we need
//      int ***chordlist;
//      int cl_len=4;
//      int chord_lengths[4]={2,2,2,2};
//      int start_pitch=10;
//      int modelist[4]={1,3,5,7};
//      int mode_length=4;
//      double  rhythmlist[]={1, 1.5, 0.25, 0.33};
//      //build chordlist
//      chordlist=(int ***)malloc(4 * sizeof(int **));
//      int r=0; //pitch literal value
//      int c=-1; //accidental value
//      int i=0; //number of chords
//      while (i<4){
//              int **temp=(int **)malloc(2*sizeof(int *));
//          fprintf(stderr,"%s\n", "fuck pointers");
//          chordlist[i]=temp;
//          fprintf(stderr,"%s\n", "pointers are cooeilo");
//               int j=0;
//          while (j<2){
//              fprintf(stderr,"%s %d\n", "r = ", r);
//              int* temp=(int *) malloc(3*sizeof(int));
//              (chordlist[i])[j]=temp;
//              int* pitch=(chordlist[i])[j];
//              pitch[1]=r;
//              pitch[2]=c;
//              r++;
//              j++;
//          }
//          i++;
//      }


//          fprintf(stderr,"%s\n", "chord list was created");
//      //
//      int temp1[2];
//      int temp2[2];
//      int temp3[2];
//      int temp4[2];
//      int *modarr[4]={ temp1, temp2, temp3, temp4};

//     //testing synth
//         synth(chordlist, cl_len, chord_lengths, start_pitch,  modelist,  mode_length, rhythmlist, modarr );

//     //let's see...
//     int ***new_list = fold_lists(chordlist, cl_len, chord_lengths, start_pitch, modelist, mode_length);
//     //print it!
//     int j=0;
//     while (j<cl_len){
//         int ** chord= new_list[j];
//         fprintf(stderr,"%p\n", chord);
//         int i=0;
//         while (i<chord_lengths[j]){
//             int * pitch= chord[i];
//                 fprintf(stderr,"\t%p\n", pitch);
//                 fprintf(stderr,"\t\t%d\n", pitch[0]);
//             fprintf(stderr,"\t\t%d\n", pitch[1]);
//             fprintf(stderr,"\t\t%d\n", pitch[2]);

//             i++;
//             }
//         j++;
//         }

//     int **correct_pitches=apply_accidentals(new_list, cl_len, chord_lengths, mode_length, modarr);


//         j=0;
//         while (j<cl_len){
//                 int * chord= correct_pitches[j];
//                 fprintf(stderr,"%p\n", chord);
//                 int i=0;
//                 while (i<chord_lengths[j]){
//                         int pitch= chord[i];
//                         fprintf(stderr,"\t%d\n", pitch);
//                         i++;
//                         }
//                 j++;
//                 }
// //testing adding rhythm to the whole shebang
//     char buff[14* 8+1];
//     buff[0]='\0';
//     strgen (buff, rhythmlist, correct_pitches, cl_len,
chord_lengths );
//         fprintf(stderr,"%s\n", buff);


// //testing aggregate synth funtion

// return 0;
// }
```