6.005 Project One Design

Project Title: An ABC Karaoke Player

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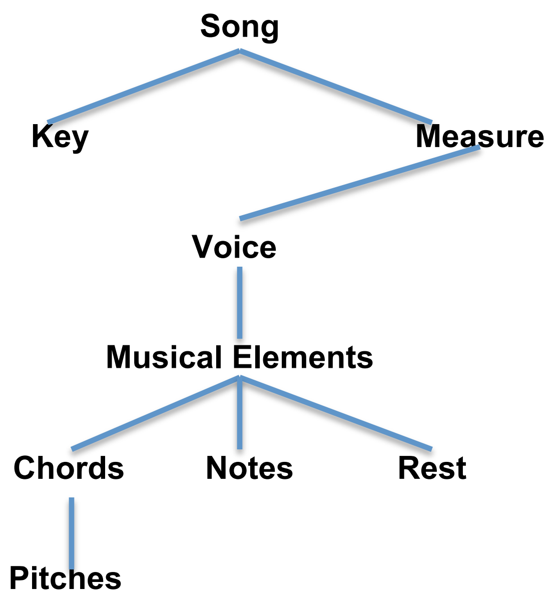
General Project Outline

File → Lexer → Parser → Listener → MIDI Generator → MIDI Player/Lyric Display

The .abc file will get fed to the lexer by way of a character stream. The lexer will output a token stream that will get fed to the parser. From this token stream, the parser will generate our abstract syntax tree. Our listener will walk along this abstract syntax tree, generating an instance of our abstract data type. This instance will get fed into the MIDI generator which will output a SequencePlayer and a LyricListener to the MIDI player, which will play the song.

Abstract Data Type Outline



Every song is a series of measures played in succession. Each song has a key which will add accidentals (sharps/flats) to every measure in the song. Additionally, each measure has it's own altered key as once a sharp or flat is introduced in the measure, it holds for all of the same notes in the measure. Each measure can be broken down into measures. Each voice within the measure is comprised of musical elements (chords, tuplets, rests) and lyrics. Instead of creating our own Lyrics class, we store the lyrics as a list of strings. Each chord is made of either one or more pitches. A single note is a chord of only one pitch. Each tuplet is made up of a series of chords. Rests are measure silence. We've elected to break down measures into voices in order to account for cases in which multiple voices hit the same note that has been altered by an accidental earlier in the measure. This ensures that accidentals will be properly maintained through the measure.

Abstract Data Type Basic Specs

- All
    - toString – takes the object and returns a string representation of it
    - equals – returns whether or not two objects are structurally equal
    - hashCode - returns a hashCode for a given object
- All Mutable Objects
    - clone – clones the object to prevent representation exposure
- Chord
    - Immutable
    - Parameters:
        - Notes: a List of notes that comprise the chord
    - getNotes – returns the list of notes that comprises the chord
    - getDuration – gets duration of the chord
    - getTicksPerWholeNote – returns the number of ticks necessary for each whole note to properly handle the rhythm of the chord
- Fraction
    - Immutable
    - Parameters:
        - Numerator – an int of the numerator of the fraction
        - Denominator – an int of the denominator of the fraction
    - evaluate – returns a double of the evaluation of the fraction (i.e. ¼ = 0.25)
    - Add – adds two fractions together and returns the result as a fraction
    - getNumerator – returns the numerator
    - getDenominator – returns the denominator
- Rest
    - Immutable
    - Parameters:
        - Duration – fraction representing the duration of the rest in terms of whole notes
    - getDuration – returns the fraction representing the duration of the rest
    - getTicksPerWholeNote – returns the number of ticks necessary for each whole note to properly handle the rhythm of the rest
- MusicalElement
    - Interface for all elements in a voice (Rest, Note Tuplet)
    - getTicksPerWholeNote – returns the number of ticks per whole note necessary to preoperly handle te rythum of the element
    - getDuration – returns the duration of the note as a fraction
- Song
    - Mutable

    - Parameters:
        - Title: string representing title of the song
        - Index: index number to determine play order if in playlist
        - Key: Key signature of piece
    - setComposer – changes the composer from the default to the string that gets passed in
    - setMeter – changes the meter from the default to the fraction that gets passed in
    - setLength – changes the length from the default to the fraction that gets passed in
    - setTempo – changes the tempo from the default to the fraction and integer that gets passed in (fraction for note, int for BPM)
    - getPitchInKey – returns the given note with proper accidentals for the song's key
    - getNotesPerMeasure – returns the number of notes in a given measure
      addMeasure – adds a single measure to the song
    - addMeasures – adds a list of measures to the song
    - getDefaultNoteLen – returns the fefaul tnote length for the song
    - getMesures – returns the list of measures making up the song
    - parseDurationFromString – retruns the duration which is the fraction represented by the string s times default note length
    - plauy – plays the song object
    - getTicksPerWholeNote – returns the smallest amount of ticks per whole note required of the sequence player
    - getBasicLyricListener – creates a basic lyric llistener object
    - createSequencePlayer – creates a SequencePLayer with the right timing for ticks and tempo
    - scheduleSequence – loops through entire song scheduling MIDI and lyric events in sequencePlayer
- Key
    - Mutable
    - Parameters:
        - keyName: a string representing the key of the piece
    - containsKey – method to test if a note is in a given key
    - alterKey – changes the mappings of notes to pitches
    - getPitch – returns the correct pitch for a specific note within a key
    - getBaseKey – returns the key for a given key signature
    - getRelativeMajor – returns relative major of a string representing a minor key
- Measure
    - Mutable
    - Parameters:
        - ticksPerMeasure: amount of ticks in each measure
        - measureNumber: number of the measure
        - repeatStartMeasure: number where repeat starts

        - alternateEnding: measure to go to on alternate ending
    - addVoice – adds a voice to the measure
    - doRepeate – get repeat start measure and set repeated flag to true
    - hasAlternateEnding – returns whether or not a measure has an alternate ending
    - getAlternateEnding – returns alternate ending
    - addLyric – adds lyrics to the measure
    - doRepeat – returns the number of the starting number of the repeat and marks it as repeated
    - alternateEnding – returns the measure of the alternate ending of a repeat sequence
    - modifyKey – modifies the key for the particular measure (adding an accidental)
    - isPitchInAccidentalKey – checks if pitch is in key of accidentals
    - getPitchInAccidentalKey – returns the pitch of the note in accidental key
    -
    - Note: to account for accidentals in a measure, for example, a measure that looks like A _A or C ^C, we have a private variable within each measure that keeps track of accidentals placed within a measure and will carry over those accidentals for repeated notes later in the measure.
- Voice
    - Mutable
    - Parameters:
        - Name: name of the voice
        - maxNotes: max amount of notes in measure (i.e. ¾ time should be 0.75)
    - addMusicalElement – adds a musicalelement to the voice
    - addLyric – adds a lyric to the voice
    - getMusicalElements – returns a list of musicalelements in the voice
    - getNotesPerVoice – returns max amount of notes in voice
    - getTicksPerWholeNote – returns the ticks per whole note required to play the voice
- Note
    - Immutable
    - Parameters
        - Pitch: Single pitch of note object to add to the Note
        - Duration: Number of ticks the note is played for
    - getPitch – returns the pitch for the given note
    - getDuration – returns the duration of the note in ticks
    - getTicksPerWholeNote – returns the ticks per whole note required to play the voice
- Pitch
    - Mutable
    - Parameters

        - C: character of the pitch to be created
        - S: string of the pitch to be created
    - accidentalTranspose – transposes a pitch up or down a number of semitones
    - octaveTranspose – transposes a pitch up or down an octave
    - transpose – transposing a note up or down a number of tones
    - difference – the difference between two notes in semitones
    - toMidiNote – returns a MIDI note of the pitch
    - lessThan – returns whether or not a pitch is less than another pitch
    - checkRep – checks the representation invariant

Grammar

Using the provided grammar, we chose what we wanted to be parser and lexer rules, making slight modifications along the way. A notable modification we made was the implementation of lexical modes. This decision forced us to have independent lexer and parser files for both the header and body. The implementation of lexical modes allowed us to more easily overcome the challenge of dealing with ANTLR's greedy token assignment, specifically when it came to text.

We've elected to make two grammars and thus two lexers and parsers for the project. One set will be used for the header of the file, the other for the body of the file. The header of the file contains information pertaining two the meter of the piece, the tempo of the piece, etc.. The body of the file contains everything else (notes, lyrics, etc.). Below are the lexer and parser rules for the grammars we've elected to use.

ABCMusicBodyLexer.g4

```
/*
 * These are the lexical rules. They define the tokens used by
the lexer.
 */

W: 'w:' -> pushMode(enter_lyrics) ;
V: 'V:' -> pushMode(enter_voice) ;

// "^" is sharp, "_" is flat, and "=" is neutral
ACCIDENTAL : '^' | '^^' | '_' | '__' | '=' ;

REST : 'z';

BAR_LINE : '|' | '||' | '[|' | '|]' | ':|' | '|:' ;
NTH_REPEAT : '[1' | '[2' ;
```

```
NOTE_LENGTH : DIGIT | (DIGIT DIVIDE DIGIT) | (DIVIDE DIGIT) |
(DIGIT DIVIDE) | DIVIDE ;
NOTE_LENGTH_STRICT : DIGIT '/' DIGIT ;

//OCTAVE : [',]+ ;

OPEN_PAREN : '(' -> pushMode(enter_tuplet) ;

OPEN_BRACK : '[' ;
CLOSED_BRACK : ']' ;

DIVIDE : '/' ;
DIGIT : [0-9]+ ;
SPACE : ' ' ;
LINE_FEED : '\n' | '\r' | '\r\n' ;
PERCENT : '%' -> pushMode(enter_comment) ;

BASE_NOTE_OCTAVE : ('C' | 'D' | 'E' | 'F' | 'G' | 'A' | 'B' | 'c'
| 'd' | 'e' | 'f' | 'g' | 'a' | 'b') ([',]+)? ;

mode enter_comment;
COMMENT_TEXT : ~[\r\n]+ -> popMode ;
END_COMMENT : ('\n' | '\r' | '\r\n') -> popMode ;

mode enter_lyrics;
END_LYRIC : ('\n' | '\r' | '\r\n') -> popMode ;
LYRIC_TEXT : ~[\_\\-\*~\\-\| \r\n]+ ;
LYRICAL_ELEMENTS : ' '+ | '_' | '-' | '*' | '~' | '\-' | '|' ;

mode enter_voice;
VOICE_TEXT : ~[\r\n]+ -> popMode ;
END_VOICE : ('\n' | '\r' | '\r\n') -> popMode ;

mode enter_tuplet;
TUPLET_DIGIT : [0-9]+ -> popMode ;
```

ABCMusicBodyParser.g4

```
abc_tune_body : abc_music EOF;

abc_music : abc_line+ ;
abc_line : element+ LINE_FEED lyric_line? | mid_tune_field |
comment ;
```

```
bar_line : BAR_LINE ;
nth_repeat: NTH_REPEAT ;
space: SPACE ;

measure : (note_element | nth_repeat | space )+ ;
element : measure | bar_line ;
note_element : note | multi_note | tuplet_element;

note : note_or_rest note_length? ;
multi_note : OPEN_BRACK note+ CLOSED_BRACK ;
note_or_rest : pitch | rest ;
rest : REST ;
pitch : accidental? base_note_octave ;
base_note_octave : BASE_NOTE_OCTAVE ;
accidental : ACCIDENTAL ;

note_length : NOTE_LENGTH ;

// tuplets
tuplet_element : tuplet_spec (note | multi_note)+;
tuplet_spec : OPEN_PAREN tuplet_digit ;
tuplet_digit : TUPLET_DIGIT ;

// A voice field might reappear in the middle of a piece to
indicate the change of a voice
mid_tune_field : field_voice ;

field_voice : V voice (END_VOICE | eol) ;
voice: VOICE_TEXT* ;

lyric_line :  W (lyric)* END_LYRIC  ;
lyric : lyric_element* lyric_text lyric_element*;
lyric_text : LYRIC_TEXT ;
lyric_element : LYRICAL_ELEMENTS ;

comment : PERCENT COMMENT_TEXT* (END_COMMENT | LINE_FEED) ;

eol : comment | LINE_FEED ;
```

ABCMusicHeaderLexer.g4

```
/*
 * These are the lexical rules. They define the tokens used by
```

```
the lexer.
 */

X: 'X:' -> pushMode(enter_index) ;
T: 'T:' -> pushMode(enter_title) ;
C: 'C:' -> pushMode(enter_composer) ;
L: 'L:' -> pushMode(enter_length) ;
M: 'M:' -> pushMode(enter_meter) ;
Q: 'Q:' -> pushMode(enter_tempo) ;
V: 'V:' -> pushMode(enter_voice) ;
K: 'K:' -> pushMode(enter_key) ;

BASE_NOTE : 'C' | 'D' | 'E' | 'F' | 'G' | 'A' | 'B'
        | 'c' | 'd' | 'e' | 'f' | 'g' | 'a' | 'b' ;

KEY_ACCIDENTAL : '#' | 'b' ;
MODE_MINOR : 'm' ;

EQUALS : '=' ;

SPACE : ' ' ;

OCTAVE : [',]+ ;

DIGIT : [0-9]+ ;
LINE_FEED : '\n' | '\r' | '\r\n' ;
PERCENT : '%' -> pushMode(enter_comment) ;

COLON : ':' ;

mode enter_tempo;
WS_TEMPO : [ ] -> skip ;
TEMPO_FRACTION : [0-9]+ '/' [0-9]+ ;
TEMPO_EQUALS : '=' ;
TEMPO_NUMBER : [0-9]+ -> popMode ;

mode enter_title;
TITLE_TEXT : ~[\r\n]+ -> popMode ;
END_TITLE : ('\n' | '\r' | '\r\n') -> popMode ;

mode enter_composer;
COMPOSER_TEXT : ~[\r\n]+ -> popMode ;
END_COMPOSER : ('\n' | '\r' | '\r\n') -> popMode ;
```

```
mode enter_voice;
VOICE_TEXT : ~[\r\n]+ -> popMode ;
END_VOICE : ('\n' | '\r' | '\r\n') -> popMode ;

mode enter_comment;
COMMENT_TEXT : ~[\r\n]+ -> popMode ;
END_COMMENT : ('\n' | '\r' | '\r\n') -> popMode ;

mode enter_key;
WS_KEY : [ ] -> skip ;
KEY_NOTE : BASE_NOTE KEY_ACCIDENTAL? MODE_MINOR? -> popMode ;

mode enter_index;
WS_INDEX : [ ] -> skip ;
INDEX : [0-9]+ -> popMode ;

mode enter_meter;
WS_METER : [ ] -> skip ;
METER_VARIANTS : ('C' | 'C|') -> popMode ;
METER_FRACTION : ([0-9]+ '/' [0-9]+) -> popMode ;

mode enter_length;
WS_LENGTH : [ ] -> skip ;
LENGTH_FRACTION : ([0-9]+ '/' [0-9]+) -> popMode ;
```

ABCMusicHeaderParser.g4

```
abc_tune_header : abc_header EOF;

abc_header : field_number comment* field_title other_fields*
field_key ;

field_number : X number? eol ;
field_title : T title_text? (END_TITLE | eol) ;
other_fields : field_composer | field_default_length |
field_meter | field_tempo | field_voice | comment ;
field_composer : C composer_text? (END_COMPOSER | eol) ;
field_default_length : L length_fraction? eol ;
field_meter : M meter? eol ;
field_tempo : Q tempo? eol ;
field_voice : V voice_text? (END_VOICE | eol) ;
field_key : K key_note? eol ;

tempo_fraction : TEMPO_FRACTION ;
```

```
tempo_number : TEMPO_NUMBER ;

eol : comment | LINE_FEED ;
meter : METER_FRACTION | METER_VARIANTS  ;
tempo : tempo_fraction TEMPO_EQUALS tempo_number ;
voice_text: VOICE_TEXT+ ;
length_fraction : LENGTH_FRACTION ;
composer_text : COMPOSER_TEXT+ ;
title_text : TITLE_TEXT+ ;
number : INDEX ;

key_note : KEY_NOTE ;

comment : PERCENT COMMENT_TEXT* (END_COMMENT | LINE_FEED) ;
```

ANTLTR Strategy

By way of developing and implementing a proper grammar, we plan on using ANTLR to generate for us a lexer to lex through the input file to generate proper tokens for later use. Similarly, we plan on utilizing ANTLR to develop for us a parser, using the properly developed parsing rules we have designed. We plan on using two lexers and two parsers. One lexer parser pair will be used for the header of the file (composer, key, etc.) and the other pair will be used to parse and lex through the body (notes, lyrics). We will also be using ANTLR to handle errors. With our correct grammar, we will use ANTLR's built in error handling to signal to the user when an .abc file does not adhere to the subset of ABC syntax we are handling.

To transform our abstract syntax tree into a format that we can cleanly play using SequencePlayer, we will be writing a Listener similar to that from the second problem set. We are planning on splitting the abc file into two parts, a header and a body, and we will have a Listener for each. Our strategy for our listeners is as follows:

Header Listener:

- Enter Header
- Enter each subpart of the header (Title, Key, etc.) and store the necessary values in an array
- Exit Header --> at this point we create a new 'Song' object using the values we obtained above (it is worth noting here that we will have an overloaded constructor for Song, so the absence of unnecessary fields is not a problem)

Body Listener:

- Enter Body
- Enter Line
- if Enter Comment --> ignore that line
- if Enter Voice --> store the name of the voice and starting measure number (we may return to a voice later; note that we do this because in our ADT, every Measure has list of Voices and a list of Lyrics. Storing the starting measure of a voice allows us to synchronize voices with lyrics and voices with other voices)
- if Enter Element
    - Exit Measure --> create new Voice, add MusicalElements from queue and LyricElements from queue and add to current Measure
    - Exit Note OR Multinote --> create new Note or Chord with pitches from Queue and add to queue
    - Exit Pitch --> new Pitch object, add to the Queue
    - Exit Measure
    - (We may enter more Measures...until new line)
    - Exit Element
    - if Enter Lyric (note that there might not be lyrics, but if there are they will always be the line after Element) -->go through syllables and symbols and add proper amount of strings representing the lyric to the lyric queue

Rather than using a stack in our listener, we've elected to create an instance of Song and add to it as our listener walks our AST.

Testing Strategy

We will be implementing a "test first" programming style. We will write tests before writing code and will write tests incrementally as we go from tackling one project to tackling the next. Similar to in the second problem set, we plan on testing each main block of our code (i.e. lexer, parser, etc.). We plan on testing our Lexer's ability to generate appropriate tokens, our parser's ability to generate correct abstract syntax trees, our listener's ability to walk along the abstract syntax tree and develop an instance of our abstract datatype, the MIDI generator's ability to generate a SequencePlayer/Lyric listener, and finally, the MIDI Player and Lyric Display's ability to properly play notes and display lyrics. To generate our tests, we will be partitioning our input space, and will use a full Cartesian product strategy to ensure maximum coverage. We will test for bad inputs, for critical input values, and will brainstorm ways that someone might try and break our code and then test for that. We will be systematic with our tests, will test early and often, and will automate the running of our tests.

- Lexer Tests
    - Tests for finding rests
    - Tests for finding notes

    - Tests for finding invalid inputs and how to deal with them
    - Tests for whitespace
- Parser Tests
    - Tests for different orderings of tokens
    - Tests for invalid token orderings
    - Tests for proper token allocation
    - Tests for invalid inputs and how to deal with them
- Listener Tests
    - Tests to check for correct walking pattern
    - Tests to check for proper generation of abstract data types that build up to make a song(notes, measures, etc.)
    - Tests to check for proper generation of final instance of abstract data type (song)
    - Tests for invalid inputs and how to deal with them
- MIDI Generator
    - Tests for proper generation of SequencePlayers given a variety of inputs
    - Tests for proper generation of LyricListener given a variety of inputs
    - Tests for invalid inputs and how to deal with them
- Tests for MIDI Player
    - Tests for different durations (upper and lower bounds)
    - Tests for different pitches (upper and lower bounds)
    - Tests for invalid inputs and how to deal with them
- ADT Tests
    - Testing equals(), hashCode(), toString()
    - Testing any as many methods of the class as possible

For an even more detailed testing strategy, see our testing strategy notes atop each testing file in our code.