Background Report: ABCD - ABC Music Notation extendeD with programming features*

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ABSTRACT

This is our project background research report for our new Domain Specific Language - ABCD, the extended language that adds programming features to the classic ABC notation. This report gives an overview of ABCD, its value, and how it is related to ABC. We also compare similiar music programming languages, discuss their design decisions. In the end, we describe a blueprint of ABCD and offer a few examples to showcase language implementatiopn.

KEYWORDS

Programming Language, Music, ABC Music Notation, Alda, Chuck, Overtone, EBNF, Parsing, Compiler

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1 OVERVIEW

Music is one of the most beautiful and ancient languages humans have created. With the advancement of technology, many solutions have been designed to facilitate the creation and spread process of music. ABC is one of the most widely used music notation forms. Even though it has great features to help musicians generate formal music sheets from scratch, its nature of being a markup language has limited its capacity for effective modification.

Many works have been done to enable musicians to systematically and efficiently generate and modify scores. However, most existing programming tools are either insufficient or not convenient to use with ABC. Our group plans to design a domain specific language called ABCD that extends ABC with common programming language features such as variables, functions, conditionals and loops. Our goal is to allow users to efficiently modify an existing ABC file or create a new piece by writing scripts in ABCD that compiles to ABC.

2 BACKGROUND AND SIGNIFICANCE

ABC music notation is a markup language for sheet music, designed to be comprehensible by both computers and humans. It uses letters, digits and symbols to represent various music features, such notes, meters, accents, etc., allowing users to type out tunes on a computer without using the special musical characters[16].

ABC was originally invented for sharing a large amount of tunes in a small-size file through email[13]. The development of different ABC software editors also offer many other advantages, such as transposition and file conversion. ABC could be useful for training one's ears and sight-reading skills. People with limited music education often find it easier to read in ABC[9].

Nonetheless, since ABC is originally designed for simple tunes, there are many limitations in handling complex music pieces, which make it difficult for musicians to represent certain features or apply certain changes to an existing piece. Some limitations are associated with the parser. The parser cannot tell from the data format what types of ABC extension of rarely-used features it may encounter, and there is no formal specification for the parser to know when the chain of elements would end[6]. ABC cannot express many of the musical features. For instance, there is little support for nested tuples, bar numbering control, and grace notes positioningend[6]. Only a subset of guitar chords have semantic meaning in ABC[5]. There is no efficient search function to find multiple occurrences of a tune pattern or a chord. As a result, users cannot systematically change a note in the multiple occurrences of a particular chord.

In general, using a computer program to make music has the following significance. It is faster, more reusable, and less prone to mistakes if the algorithms in a musician's mind can be represented by computer algorithms. A music composer may use programs to realize imagined and novel music that's unperformable by humans or that requires an amount of calculations unthinkable without a computer. By defining different functions, one may enhance a composer or an instrumentalist's operations in many ways[8]. Similarly, the motivation of this project is to expand and empower ABC

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so that users can perform operations more effectively by programming in ABCD. An example would be to add a notes to multiple occurrences of a tune pattern at the same time. Since ABCD would eventually be compiled into ABC, it is not our intention to resolve the limitations related to the design of the ABC language itself, such as changing the parser, or add new symbols in ABC so that it can represent more chords.

3 SIMILAR WORK

We have studied 3 similiar music programming languages and list what they have achieved, what they are missing, and how ABCD will be different from them.

3.1 Alda

Alda is a music programming language intended for live-coding and composing music using only a text editor. It has similar music code syntax to abc, with a goal of being understandable and usable by musicians with no programming experience[20]. Alda supports inline Clojure, a dialect of lisp[11], giving it rich programming capabilities. It can be exported to MIDI[21], which can in turn be used to generate sheet music using software like MuseScore[4].

Alda appears to satisfy most of the goals of ABCD. The only goal not addressed by Alda is abc interoperability (through either translation or inline use). Considering the significant size of the abc corpus and the large amount of software designed to work with abc, we believe it will be valuable to enable native programmatic modification and generation of abc through the ABCD domain specific language. As an alternative, Alda could be extended with features to import and export abc, but this will require abc users who want programming capabilities to learn a brand new language and use a longer pipeline, at least for modification (import abc file to Alda, modify it, and export to ABC).

3.2 Chuck

3.2.1 What is it about? Chuck is a powerful programming language designed for real-time sound synthesis and music creation[19]. It has the following great features[18]:

- Strongly-timed: Chuck allows programmers to control and reason about time precisely and expressively. It is an extremely important feature in audio programming paradigm.
- Deterministic concurrency model: Chuck is able to run multiple processes (shreds) in parallel in its virtual machine. Combined with time-based model, it empowers end-user programmers to have arbitrarily fine granularity and create complex audio synthesis programs.
- Dynamic control rates: Programmers can manipulate the control rates (the manner with which a shred advances its way through time[18]) as they want and the control rates can dynamically vary with time.
- Live-coding: Chuck allows programmers to modify the code on the fly without recompiling.

3.2.2 What has it achieved?

Language Design: Chuck is first released in 2003[10]. Since then, it has evolved into a very robust and complete audio programming language. It is static typing. Besides, the designer of Chuck has includes most of the modern language features in this languages. For example, it has primitive types such as int, float, void etc, reference types, variables, arrays, functions, control structures, and even object oriented features. Furthermore, since Chuck is a programming language specialized in music, it contains many special designs such as ‘time‘ and ‘dur‘ type for users to easily manipulate time, ‘unit generator‘ and ‘unit analyzer‘ functions that are convenient to modify big chunk of music.

Applications: The Chuck has found a variety of applications in music research and music creation. First of all, it is able to turn computers into instruments. Chuck has powered two "computer music" orchestras, namely PLOrk (Princeton Laptop Orchesta) and SLOrk (Stanford Laptop Orchestra). Besides, Chuck has served as experimental platformfor on-the-fly machine learning for real-time musicinformation retrieval prototyping[10]. In addition, it has also been applied in the development of music mobile-apps like Ocarina and Smule[10].

3.2.3 How our language is different? The success of Chuck demonstrates the significance of the role of programming language plays in music and audio produciton. Designing and applying programming lanuages in generating and modifying music is definitely a valuable task to do. And Chuck is a great example we can learn from when designing our own Domain Specific Language which is customized for ABC music notation. There are many language designs in Chuck that we can follow. For instance, we should definitely include primitive types such as int, float, and music specific types like duration, note etc. Moreover, having functions and common control structures like conditional statements and loops will also be helpful. With that being said, we will not copy all the features from Chuck into ABCD. What we will do differently is that ABCD will contain ABC related data types to natively support ABC notations. Besides, we will also provide build-in SDK to systematically modify ABC files.

3.3 Overtone

Overtone is an Open Source toolkit for designing synthesizers and collaborating with music. It provides[3]:

- A Clojure API to the SuperCollider synthesis engine
- A growing library of musical functions (scales, chords, rhythms, arpeggiators, etc.)
- Metronome and timing system to support live-programming and sequencing
- Plug and play MIDI device I/O
- A full Open Sound Control (OSC) client and server implementation.
- Pre-cache - a system for locally caching external assets such as .wav files

Overtone’s idea is about sound generation. "Let me answer from the synthesis perspective - which is one of my main interests. Learning to design new synthesisers is a pretty dark art, and most of the books/resources I found take a very theory-centric stance which I found to not be particularly useful." Said the author of Overtone, Sam Aaron[1]. The current design of ABCD is just let it compile to ABC, and let ABC deals with the sound generation part. The

ultimate version of ABCD can be directly interpreted to play sound, so how Overtone hooks up with SuperCollider can be case-studied for our own implementation.

Another advantage of overtone is about collaborative programming. Overtone provides an API for querying and fetching sounds from http://freesopund.org and a global concurrent event stream[3]. Sharing music is a huge part of enable people to write music. ABC is a great source in text format to share music, and Overtone is a great source to share music in computer programs. However, to understand Overtone program is not as straight forward as reading ABC notation. ABCD will have programming feature, so we enable both sides — for people who writes complicated music programs and for people who just write plain ABC with some syntactic sugar to make their life easier.

From a language design perspective, Overtones design is based on Clojure. Two core component of Overtone are synths and ugens. Synths are trees of ugens. Ugens are standard Clojure functions and return data-structures which are understood by the macros demo and defsynth. You can pass arguments to the ugen functions to specify their behaviour. Synths are not ugens. Calling a ugen function returns a data structure which can be used in a synth design. Calling a synth as a function triggers (i.e. plays) that synth.[2] The story of overtone gives us some hints on the language design — we probably need to define what are the automics in the music world and make them first-class members of our language. However, for a sequence of sounds, they are probably playable/translatable objects.

4 POTENTIAL PROJECT

4.1 Features

4.1.1 Variables: Most programming languages have some form of identifiers. ABCD will as well – this allows us to easily refer to functions and values. In the case of ABCD, this may include small and large chunks of music code. ABCD will support variables rather than immutable values. Variables lend themselves to modifying existing music code, which is one of our use case goals for ABCD. They also provide a mechanism for applying repeated transformations to a piece of music code that may or may not occur contiguously in the file (and therefore in evaluation). Mutation using variables is a feature supported in most popular programming languages. Moreover, abc encodes a music score, which represents a sequence of notes to be played over time, and it is encoded for the most part in the same order as the notes. Similarly, mutation is driven by the flow of time. Applying a sequence of transformations to a variable is more obviously sequential than the nested function applications common in functional programming. As a result, a more imperative programming paradigm will be easier to reason about when interwoven with abc music code.

4.1.2 Functions: Functions are a basic component of a programming language for performing a specific task. ABCD would support users to write functions such as (but not limited to) the following:

- A function that takes a tempo and change it to a different tempo.

- A function that takes a whole music score and output the bar numbers along with the piece.

- A function that takes a note "n" and a chord "c", and randomly generate another note "n2" according to the "c", to harmonize "n". It may also support first-class functions. For instance, if a user wishes to change all 3/4 bars containing a certain note pattern to 4/4 by adding a rest to the end, there needs to be a search function which takes a function (a conditional in this case) as its predicate or search criterion.

In addition, functions defer evaluation and abstract over arguments. Users can input a tune pattern to a function but wait for a bar number from another function, so that they can modify the tune pattern in that bar number alone.

4.1.3 Loops: All high-level programming languages provide different forms of loop for the purpose of executing one or more statements up to a desired number of times. In the domain of music, it would be useful for performing search, systematic insertion, modification, and generation of music.

Imagine a musician is trying to perform the following operation: search for all occurrences of tune "GFERE2" and return their bar numbers. One can easily use a loop to iterate through all the bars or movements (depending on what the variable is) of a piece. This operation may be useful when a musician needs to change a note in some occurrences of a same pattern, but she has to examine the context of those occurrences first. One may think "Ctrl+F" would simply do the job, but ironically, it's not even supported in the most popular ABC editor[15].

Another example is to generate a sequence of semi-tone of length 30. Instead of manually typing 30 notes, one can simply use loop to generate a scale by increasing the key by half in each iteration.

4.1.4 Conditions: The conditional statment is an extremely powerful and important portion of a fully functional programming language. It enables the programmers to test a variable against a value and execute in one way or another. Thus, ABCD will include if-else statement in order to help end-users control the dynamic execution flow of their programs. Syntatically, we will follow the standard conditional statement syntax and its semantics. Namely, a 'if' key word followed by a condition statement, followed by a truth statement and an optional 'else' key word and a falsity statement. The programmers can also chain conditional statements by using the 'if else' key word.

As an example, a user may want to change the speed of a score, but only if the tone is D. A conditional statment will be handy here.

4.1.5 File Importing: In order to create modifications of existing ABC tunes, we need access to the code contained in the files that house those tunes. To that end, ABCD will support inclusion of files by name. Files can be imported into any part of a file, allowing the inclusion of that file's whole contents. Files can also be imported into a variable. This allows the programmer to selectively keep parts of the file, such as the body of a tune, the header, or a block of music code. It also allows direct modification of this copy of the file's contents.

As an example, a user may wish to change every instance of a chord in an ABC file. They can import the contents of that ABC file into a variable in a new ABCD file. They can define a "replace all" function that takes in 3 chunks of music code or text, replacing all instances of the second argument with the third in the first.

The user can then call the replace all function, passing in the variable containing the source file, the chord to be replaced, and the replacement chord. The variable will now contain the new, modified version of the original ABC tune, which can then be modified further or added to the ABCD file body to be compiled to ABC. Import statements will be useful for a second reason, seen in most other programming languages: including library files. It is likely that users will want to reuse functions they write, and possibly chunks of music code such as melodies or chord progressions. By defining functions and variables in library files, they will be easy to import and use in any other ABCD file. For example, the "replace all" function described above will be useful when editing any tune that requires something to be replaced multiple times.

Importing an ABC file can be simple: include the whole text of the file. However, it may be worth allowing the header and body of a one-tune file to be imported into two separate variables. It would not be hard to write a function to do this, however, so this could be included in a standard library.

In addition to a header and body, an ABCD file has definitions. Again, the ABCD could be included as a big block of text, but it may be more useful to treat definitions as separate from the body and header of an ABCD file when importing. This depends in part on whether definitions are interleaved with music code, which could affect how they are interpreted within the body of the file; or if they are defined up front in a separate definitions section.

4.2 Concrete Syntax

We will design concrete syntax for ABCD to support the following features: variables, conditionals functions, loops, and import statements.

4.3 Parse into AST

After some research, we have found a few implmentations of parsing ABC. Sergi Mansilla has implemented an ABC parser in JavaScript, which parses the ABC notation to a JSON object[14]. Remo Dentato has developed a C library to parse the ABC notation[7], however, the source code can no longer be found on the website and the usage description is quite complicated. However, on Dentato's website, it offers some high-level design graph of the scanner and documentation on tokens. Hans Höglund has implemented a parser in Haskell[12]. Höglund's implmentation has a few limitations such as do not support volatile features, text strings, and macros. abc4j is a Java library that provides API to handle ABC music notation using Java. The source code can be downloaded on https://code.google.com/archive/p/abc4j/source. However, it only supports the v1.6 standard of ABC (the current version is v2.1). There are many other people who tried to implment parser for ABC but failed or stopped their project.

Mansilla's implmentation seems to be the easiest one to comprehend and can be adopted effortlessly if we implment ABCD language in JavaScript. The parser is based on PEG.js(parsing expression grammar), a simple parser generator for JavaScript that produces fast parsers with error reporting[22]. It integrates both lexical and syntactical analysis. The parsing expression grammar formalism is described to be more powerful than traditional LL(k) and LR(k) parsers.

In order to build a prototype, we think of a simple implementation in Python that only parses a subset of ABC notation(bars, title, etc.), because Python is good for its string manipulation capabilitites. In our full project, we plan to use a parser generator to completetly contain the whole ABC language specification.

For example, for the following ABC code.

```
X:1
T:Notes
M:C
L:1/4
K:C
C, D, E, F,|G, A, B, C|D E F G|A B c d\
|e f g a|b c' d' e'|f' g' a' b'|]
```

We will parse it to an AST like this:

```
{
id: 1,
title: "Notes",
meter: "C",
length: "1/4",
key: "C",
tune: [ // tune is an array of bars
    [{ note: "C",
       length: 1},
     { note: "D",
       length: 1},
     { note: "E",
       length: 1},
     { note: "F",
       length: 1},],
    [{ note: "G",
       length: 1},
     { note: "A",
       length: 1},
     { note: "B",
       length: 1},
     { note: "C",
       length: 1},],
       ...
    [{ note: "f'",
       length: 1},
     { note: "g'",
       length: 1},
     { note: "a'",
       length: 1},
     { note: "b'",
       length: 1},],
]
}
```

4.4 Compiler

An ABC file consists of an optional file header, followed by at least one ABC tune. A tune represents a song, and consists of a tune header with information about the whole tune, such as key, meter, and composer; and a body, which consists of actual music code[16]. Just as all ABC code is valid ABCD, an ABC file is a valid ABCD file. An ABCD file can have all the same parts as an ABC file, plus

optional definitions. These can be function definitions and variable definitions. Functions can be called anywhere in the header or body, as well as in a function or variable definition. Variables can be referenced or assigned in all the same places: header, body, function definitions, and variable definitions.

An ABCD file does not have to contain tunes; it may optionally contain only definitions. In this case, it serves as a library file to be included in other ABCD files, providing functions and music code for reuse.

ABCD files will be compiled to ABC files. This will allow us to leverage the many existing software programs that support abc[17]. These software programs include music players, pdf writers, and more.

The compilation step will include parsing and interpretation of the ABCD file. ABC code found in the header and body will be unchanged in the resultant ABC file. Parsing and interpretation will evaluate all ABCD definitions and expressions. Each expression found in the header or body will be replaced with the result of its evaluation in the ABC output file. This allows the creation and use of functions that are designed to be called inline in the body to expand into music code. It also allows variables to be mutated partway through the body, and its modified value used for the rest of the tune. For example, a variable containing a C major triad (C E G) may be used in the beginning of a song, but mutated so that after the bridge, it has a major 7th (B) added, giving the modified chord wherever that variable is used for the rest fof the song. An ABCD file with no tunes will not produce any file when compiled.

5 LIMITATIONS

Using a computer to make music also has some limitations in general. The complexities of music are so numerous, undefined, interconnected, and is related to so many variables and random factors, that any reproduction would inevitably become compromised. There are many emotional nuances produced by real people that a synthesis procedure cannot simulate[8]. Given the advantages and disadvantages of programming music, it comes down to an individual's goal whether to use a programming language to make music.

ABCD also has certain limitations, despite all the convenience. It does not support certain features, such as recursion. Users would need to either use loops to simulate recursions or define their own recursions. As mentioned before, ABCD is also limited to the capacity of ABC since it compiles to ABC. It offers expedient operations on ABC but cannot provide extra features beyond ABC.

6 CONCLUSIONS

In summary, ABCD is designed to enhance ABC with features including variables, functions, conditionals, loops, and import statements. The motivation is to empower users to generate or modify a piece of music more efficiently than they would in ABC. Future implementation is needed to fulfill all the desired goals.

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