

INTRODUCING MUSIC TO NOOJ

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Introduction

Many will agree that music is a language (Simões et.al., 2007), and that as such it can be analysed just as easily (or difficultly) (Nettl, 1958). If we can say that words of a language are coded using letters, numbers and symbols (like: *3-year old boy*), and language is something that we venture to analyse, than, if we code notes using the same set, we should be able to analyse it as well.

NooJ has so far been successfully used in various analyses of textual data in a wide variety of languages¹. But, could NooJ read musical notes? If not, how could we make NooJ read musical notes? And even if we make NooJ read music, what can we do with that data?

This is just what our project is about. We intend to explore the possibility of using NooJ for the analysis of sheet music in order to find out, among other possible answers, what notes a composer uses the most, what octave does s/he prefer, what are similarities among the same musical period compositions etc.

Since NooJ does not understand notes², we need to translate them into text before starting any kind of the analysis. For this purpose we are using the *LilyPond* program's notation for musical notes and a free online library of classical music, as a courtesy of *Mutopia* project (Mutopia, 2013). Using this raw data, we created a NooJ environment that is able to read and process sheet music. Upon creating a dictionary of terms used in sheet music notation, 20 syntactic grammars for processing sheet music were created to get us started with the analyses of music.

¹ Acadian, Arabic, Armenian, Belarusion, Bulgarian, Catalan, Croatian, French, English, German, Greek, Hebrew, Hungarian, Italian, Latin, Polish, Portuguese, Russian, Serbian, Slovene, Spanish, Turkish, Vietnamese.

² NooJ „only“ understands the variants of DOS, EBCDIC, ISCII, ISO, OEM, Windows, MAC, UNICODE, Arabic ASMO, Japanese EUC and JIS variants, Korean EUC and Johab, character encodings (Silberztein, 2003:64).

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Although some similar experiments were conducted using for example Cunningham-Grout-Bergen model (Cunningham et.al, 2005) or Weka open-source data mining toolkit (Simões et.al., 2007), this is, to our knowledge, the first attempt to describe the language of notes with the help of NooJ.

The Scope of our Research

If we observe musical notes as letters of an alphabet different from the Latin alphabet, one approach could be to convert that 'foreign' alphabet into the Latin one to make it easier to analyse. This is the road we choose to follow in order to introduce music to NooJ development environment. We explain the conversion in more details in sections on building the musical dictionary and syntactic grammars.

There are numerous linguistic-like procedures that can be undertaken after building the musical dictionary (Nettl, 1958). These can include stylistic analysis of respective authors, composer comparison or musical genre detection. At this stage of the project, we have decided on the following: counting the number of single tones, chords, beams and slurs (see Figure 1).

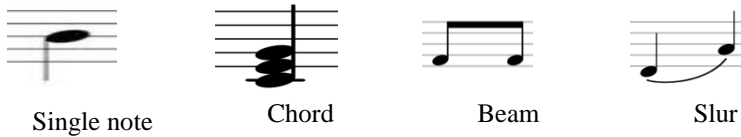


Figure 1 - Types of notes recognized by the syntactic grammars

In the following sections we will explain each step in more details.

Sample Compositions

Selecting a Sample

As a demonstration, and a mind opener, of what can be done with NooJ considering the musical sheets, we selected two compositions for the preliminary analysis. The selection includes two sonatas written during the classical musical era. The first one is written by W.A. Mozart in 1777 and the second one by L.van Beethoven in 1794/95.

Our source of musical material is a library of free content sheet music placed on the Mutopia Project web site. And, while Simões et.al. (2007)

analysed the monophonic scores for violin, cello, flute, recorder and clarinet, at this stage of our research we will only analyse the scores for piano.

As our selection of scores shows, we used several criteria when choosing the works: the composers are to be from the same musical era (we decided on classical musical period), they have to have the same form of music (sonata), they are played with only one instrument (piano) without vocal sections, they are prepared for the Mutopia by the same person³ and are of approximately the same size.

Out of 1736 pieces of music available at the time when we started the research, there were 367 that were written for the piano. From that number we excluded 57 Traditional Swedish Folk Dances, 2 Anonymous pieces, 15 single representatives of a musical era and 175 pieces that were prepared for Mutopia by the author that has less than 2 pieces in his/her collection. From the remaining files, we excluded all the pieces that were shorter than 6 pages or longer than 10 pages which left us with 25 compositions (and three composers: Schubert, Beethoven and Mozart). However, since we needed to satisfy one more criteria (that the compositions were prepared by the same person), we were left with only one Mozart's Sonata (*Piano Sonata in C Major – KV 309 – 1st Part*) and 11 Beethoven's Sonatas (we chose *Sonata No.1 – 1st Movement: Allegro* since it is of similar length as Mozart's Sonata).

Our sample compositions have 8 966 tokens (2519 of which are notes) and 6 472 tokens (1 886 of which are notes), respectively. The two pieces seem to be of quite different sizes, but the numbers are a bit misleading due to the value of notes used in each piece. In fact, they both have the same time signatures (4/4) and the number of bars is by only 6 larger in Beethoven's sonata⁴. Thus, we can conclude that the two pieces are of the similar length.

Sample Text Modifications

We cleaned up both compositions by removing some forms of notations that were added to each piece either as an additional instructions for the layout design (paper-height, paper-width, line-width, padding, font-size, colour etc) or information about the person preparing the notation for the Mutopia site that were placed under the header section marked as

³ LilyPond software allows certain amount of freedom when describing notes, so with this restriction, we wanted to make sure to have the unified notations in both compositions at this time of our research.

⁴ Beethoven's Sonata has 153 bars, and Mozart's has 147.

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`\header{}` like `mutopiatitle`, `mutopiapoet`, `mutopiacomposer` etc, and the information that was placed inside the footer section marked as `footer = "Mutopia-yyyy/mm/dd - number"`. The data we deleted from the sample text was not considered to be of any relevance⁵ for our research and since it produced lots of noise, we decided to erase it at this stage of the project development so we can concentrate more on the notes themselves. However, we have left the trail to the original data by replacing the text with self-explanatory tags.

The following modifications were thus made trying to keep the reference to the original: everything marked as `footer = "..."` in the original LilyPond file was replaced with the notation `<footer>`, `\midi {...}` was replaced with `<midi>`, `\paper {...}` was replaced with `<paper>`, `\layout {...}` was replaced with `<layout>`, `tagline = \markup ...` was replaced with `<tagline>`, all the comments were replaced with a tag `<comment>`.

Building the musical dictionary

We started our musical NooJ journey with the construction of musical dictionary. Its content can be divided into two main parts (see Table 1 for examples):

1. the elements that describe the music:
 - a. note,
 - b. pause,
 - c. ornament,
 - d. grace note,
 - e. dynamics,
 - f. global information;
2. the elements that describe everything else on the page:
 - a. description of composition (placed inside the header section of the document),
 - b. note blocks (places where to put notes),
 - c. page layout information,
 - d. reference to deleted page descriptions/printer instructions.

With the help of LilyPond manual we described and manually added to the NooJ dictionary various musical terms. For the purpose of this re-

⁵ The purpose of our reasearch is not to parse the LilyPond notation only to parse the musical notes presented by the LilyPond notation.

search, we designated each of the musical terms one of the five categories: *N*, *PA*, *DYN*, *ORN* and *GN*.

Elements that describe the music	Elements that describe everything else
<pre>#use muzicke_note.nof # N= notes c,N+Octave=0+FLX=TRAJANJENE+LAN G=Nederlands d,N+Octave=0+FLX=TRAJANJENE+LAN G=Nederlands #PA =pause r,PA+Length=U # ORN = ornaments staccato,ORN # GN = grace notes grace,GN acciaccatura,GN # DYN=changes in dynamics cr,DYN+Value=crescendo f,DYN+Value=forte</pre>	<pre>#inside the header header,HEADER title,HEAD+Value=Title+DRV=HEADER composer,HEAD+Value=Composer+DRV=HEADER #NB=note blocks - place where to put notes score,NB+Level=0 new GrandStaff,NB+Level=1+UNAMB new StaffGroup,NB+Level=2+UNAMB new Staff,NB+Level=3+UNAMB #PL= page layout <comment>,PL+comment+UNAMB <footer>,PL+footer+UNAMB markup,MARK large,FONT+Value=markup</pre>

Table 1 - Examples from musical NooJ dictionary

N stands for the **note** and, at the dictionary level, describes only the name of the musical note (c, d, e, f, g, a, b). This is the only category in the dictionary that has FLX property (see next section for the details). **Pause** is marked as PA to distinguish it from other notes on the sheet.

DYN marks the changes in **dynamics** or the volume of the note (e.g. *pp*, *pppp*, *ffff*, *fp*, *sf*, *sfz*) and has an additional attribute Value (e.g. *piano*, *forte*).

Piano Sonata Opus 2 No 1 (1st Movement)
Ludwig Van Beethoven

The image displays the first two systems of musical notation for the first movement of Beethoven's Piano Sonata Opus 2 No 1. The music is written for piano in G major (one sharp) and 2/4 time. The first system begins with a piano (*p*) dynamic. The second system features a fortissimo (*ff*) dynamic. The notation includes treble and bass staves with various note values, rests, and dynamic markings.

Figure 2 - Musical notation

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Different types of **ornaments** (e.g. *staccato*, *arpeggio*, *trill*, *prall*) are marked as ORN while **grace notes** (e.g. *grace*, *acciaccatura*, and *appoggiatura*) are marked as GN.

Now, instead of making NooJ read musical sheet as shown in Figure 2, it reads the notes' descriptions as presented in Figure 3.

```
\header {
  title = "Piano Sonate Opus 2 No 1 (1st Movement)"
  composer = "Ludwig Van Beethoven" ...}
\score {
  \new GrandStaff <<
    \new Staff = "up" {
      \clef treble
      \key f \minor
      \time 4/4
      \tempo 4 = 190
      \repeat volta 2 { \partial 4 c'4\p\staccato^markup { \large \bold "Al-
legro." } f''\staccato aes''\staccato c''\staccato f''\staccato aes''4.( \times 2/3 {
g''16[ f'' e'' ] f''4\staccato) r4 g''\staccato c''\staccato e''\staccato g''\staccato
bes''4.( \times 2/3 { aes''16[ g'' f'' ] g''4\staccato) r4 \acciaccatura c''16
aes''4.\sf( \times 2/3 { g''16[ f'' e'' ] f''4\staccato) r4 \acciaccatura c''16
bes''4. ...}
```

Figure 3 - Musical sheet – LilyPond notation

Inflectional Grammar

As already mentioned, there is only one category in the dictionary that uses the FLX property and that is the note category - N. In addition to the category, the note also has 3 more properties defined: *octave*, *language* and *FLX*.

All the notes from the main dictionary are described as belonging to the primary octave marked as <Octave=0>. Octave, together with the information about the length, changes after applying syntactic grammar for defining the complete⁶ note.

Each note has accidental suffixes (**sharp** - sharp, **flat** - flat, **dblsharp** - double sharp and **dblflat** - double flat notes) which were the main reason for building inflectional grammar. Since LilyPond supports 11 different

⁶ The complete note consists of a note name, octave, length and ornament if available (see the next section for details).

sets (languages⁷) of note names, which differ not only in the note names but accidental suffixes as well, we decided to describe these changes using FLX property. So, depending on a language, the paradigms were marked as TRAJANJExy – where xy stands for the first two letters of a language it represents.

For example, the suffixes for accidentals in Nederland's notation are described as:

TRAJANJENE = <E>/main + is/sharp + es/flat + isis/dblsharp + eses/dblflat;

This way, the concordance for <c> will find all the forms of note 'c': *c*, *cis*, *ces*, *cisis* and *ceses*. We can compare this to the results of a search for the forms of a verb <play> which would include: *play*, *plays*, *playing* and *played*.

Syntactic Grammars

We build 20 syntactic grammars to complete our goal in finding all the single notes, chords, beams and slurs. We can divide them in the following manner:

- **disambiguating f** - 'f' is a name of a note, but it is also used for *forte* i.e. as dynamics in the case it is preceded with a backslash;

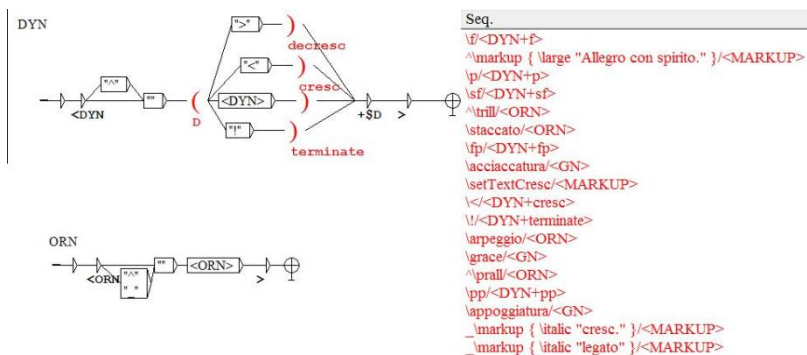


Figure 4 - Description of dynamics and ornaments with an extract of related concordances

⁷ Nederlands, Catalan, Deutsch, English, Espanol, Italiano, Norsk, Portugues, Suomi, Svenska and Vlaams.

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- **markers** - all the words that are not part of a note but are written inside the note blocks (style information) are tagged as <MARKUP>, while ornaments, grace notes and dynamics that come with obligatory backslash (\) and optional position markers (^, _) before the ornament itself are tagged as <ORN>, <GN> and <DYN>, respectively (Figure 4);
- **brackets** – 4 types of brackets are used in the text: ‘()’ for slurs, ‘[]’ for beams, ‘<>’ for chords and curly brackets ‘{ }’ that have several uses (check LilyPond Music Glossary for details); each bracket has been marked as <BRA+Open+S|B|C|V> or <BRA+Close+S|BC|CC|VC> (Figure 5);
- **octaves** – in LilyPond notation, octaves above the primary octave are marked with 1, 2, 3 or 4 apostrophes, while the octaves below the primary one are marked with 1, 2, 3 or 4 commas if found immediately after a note or pause; in NooJ we annotated the first set as <OC+Octave=1|2|3|4> and the second one as <OC+Octave=m1|m2|m3|m4> where ‘m’ stands for ‘minus’ (Figure 5);

Seq.	Seq.
(/<BRA+Open+S>	a,./<OC+Octave=m2>
)/<BRA+Close+SC>	a,./<OC+Octave=m1>
[/<BRA+Open+B>	a'./<OC+Octave=1>
]/<BRA+Close+BC>	a''./<OC+Octave=2>
{/<BRA+Open+V>	aes'./<OC+Octave=1>
}/<BRA+Close+CV>	aes''./<OC+Octave=2>
</<BRA+Open+C>	ais''./<OC+Octave=2>
>/<BRA+Close+CC>	b,./<OC+Octave=m2>

Figure 5 - Excerpt of concordances for Brackets <BRA> and Octaves <OC> grammars

- **single notes** - 11 grammars that follow describe the complete notes (including pauses) taking into account the name of the note (c, d, fis, ces etc.), octave (-4..4), length (1, 2, 4, 8, 16, 32, 64, 128) and additional ornamentation (staccato, arpeggio, trill, prall, fermata) that the note may or may not have. If there is a notation indicating grace note⁸ prior to the note name, this notation is also considered to be part of the note it proceeds. The first grammar from this set

⁸ Small ornamental notes whose length is not included in the total length of the bar.

recognizes single notes (Figure 6), including pauses, with all the information given next to the note name.

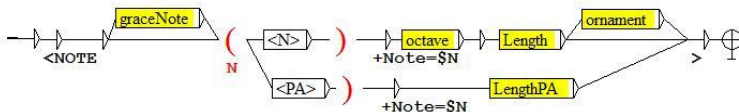


Figure 6 - Grammar recognizing single notes with all the information immediately after the note name

Entire recognized string is marked as **<NOTE, Note=note name +Octave=Octave+Length=Length+Ornament=Ornament>**⁹. Of course, it is quite natural for a note to appear without ornament, but this cannot be said for *Length* since all notes must have this attribute.

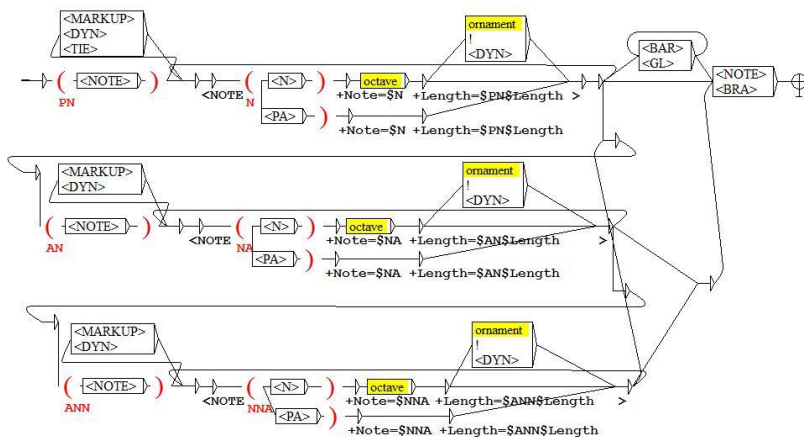


Figure 7 - Recognizing lengthless notes positioned between two complete notes

However, LilyPond's notation allows this value to be inherited from either the last note that has this information and is positioned any number of places before the note we are analyzing, or from the first

⁹ Note name =c|d|e|f|g|a|b|their alternations (cis, ces, dis, des etc.);
 Octave= 1|2|3|4|m1|m2|m3|m4;
 Length =1|2|4|8|16|32|64|128;
 Ornament = trill|staccato|arpeggio|prall.

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note that has this information and is positioned after the first closed chord bracket that can be any number of places after the note we are analyzing.

For this reason, we had to introduce 10 more syntactic grammars that search for those notes that are placed between two complete <NOTE>s and, depending on the context, inherit the Length property either from the complete note that is placed before it (Figure 7) or after it.

- **set of notes** - the last 5 grammars are recognizing chords, beams and slurs where found as separate instances, or when in combination with one another. Only after all the notes are annotated with their complete information, we apply the chords/beams/slurs grammars so that their annotations can inherit all the information about the <NOTE>s they consist of. At this time, we are only adding information about the note name (Figure 8), but this can be augmented with the information about each note's octave, length and/or ornament.

Seq.

```
a"^\prall([ g"^\staccato])/<SLUR+Notes=a<BEAM+Notes=a g> g>
g"8([ e" ])/<SLUR+Notes=g<BEAM+Notes=g e> e>
g"8.^\trill([ fis"32 g" ] d""4 e"")/<SLUR+Notes=g<BEAM+Notes=g fis g> fis gd e>
<c"! fis" c"!>4\fp\arpeggio/<CHORD+Notes=c fis c>
<fis a d'>/<CHORD+Notes=fis a d>
<g, g>\staccato/<CHORD+Notes=g g>
<g, g,>2/<CHORD+Notes=g g>
dis"^\staccato[ a"^\staccato c"^\staccato fis"^\staccato]/<BEAM+Notes=dis a c fis>
e"8.[ d'16 c'8. b16]/<BEAM+Notes=e d c b>
g32[ bes d' ]/<BEAM+Notes=g bes d>
a8( c' a c' f' c' f' e' e' e' c' c' c' c' f a f d' )/<SLUR+Notes=a c a c f c f c e c e c c c c f a f d>
b,16\ff( g fis g a g fis g b,4 )/<SLUR+Notes=b g fis g a g fis g b>
f'( c" aes" g" fis" )/<SLUR+Notes=f c aes g fis>
f"^\prall( e"^\staccato )/<SLUR+Notes=f e>
```

Figure 8 - Excerpt of concordances for chords, beams, slurs and their combinations

After applying all of the grammars to the composition, we are able to determine the number and type of single notes used, note values, intervals, chords, beams and slurs. The results (see section on Results for more details) we get from our sample compositions look as a good start for any further analysis of musical sheets transcribed using LilyPond notation.

Results

After applying the linguistic analysis, we were able to check the distribution of single notes in each Sonata. The results show that Beethoven (Table 2) used the most note C among natural notes, sharp F among sharp notes and flat A among flat notes. There are no sharp C, sharp D, sharp E, sharp G, sharp A or sharp B in his Sonata.

	c	d	e	f	g	a	b	R
<i>natural</i>	356	52	93	242	193	19	42	194
<i>flat</i>	6	148	161	11	20	179	168	/
<i>sharp</i>	0	0	0	2	0	0	0	/
1886	362	200	254	255	213	198	210	194

Table 2 - Distribution of notes in Beethoven

Mozart (Table 3) also used the note C among the natural notes and sharp F among sharp notes the most, but used flat B among flat notes and did not use sharp B, or flat C, F and G at all.

	C	d	e	f	g	a	b	r
<i>natural</i>	399	379	271	157	391	246	243	146
<i>flat</i>	0	5	16	0	0	13	37	/
<i>sharp</i>	40	18	2	124	30	2	0	/
2519	439	402	289	281	421	261	280	146

Table 3 - Distribution of notes in Mozart

We can go even further in our analyses and see more detailed distribution for each note (see Table 4 for an example), depending on the octave and length as well.

Note	Oct.	Len.	#
a	1	1	2
		2	4
		4	18
		8	90
		8.	4
		16	41
		32	2
	2	1	1

Note	Oct.	Len.	#
a	2	2	4
		4	9
		8	23
		16	31
		32	3
	m1	2	2
		4	6
		8	3

Note	Oct.	Len.	#
a	m1	16	2
	m2	2	1
aes	1	8	8
		16	2
ais	2	8	3
	2	8	2

Table 4 - Detailed distribution of Mozart's note 'a' with all its variants

The distribution of top 5 chords, beams and slurs for both compositions is given in Table 5. At this time, we only considered the note names inside the chords, beams and slurs without taking into account the octave or the length properties.

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Mozart			Beethoven		
<CHORD>	<BEAM>	<SLUR>	<CHORD>	<BEAM>	<SLUR>
25 <c c>	4 [c e g]	10 (e f d c)	7 <f aes c>	6 [g f e]	5 (aes g f e f)
18 <g g>	3 [a d a d]	8 (f e)	5 <c f aes c>	4 [aes g f]	4 (a c bes)
13 <c g>	3 [b d b d]	7 (a g)	4 <c c>	3 [c bes a]	4 (bes aes g f g)
10 <a a>	3 [e d c b]	6 (b a)	4 <des des>	3 [des c b]	4 (f f e e)
7 <c e>	3 [f e]	6 (c b)	4 <e g bes c>	3 [ees des c]	4 (fes ees des bes g)

Table 5 - Distribution of top 5 chords, beams and slurs

If it is true that an individual (even brief) composition carries stylistic tendencies and structural rules as Nettle (Nettl, 1958) argues, than our results could be used to prove that other works of our test authors would show similar results. Well, at least now we have a way to prove or disprove this.

References

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