Rhythm Inference Helping Writing Music Scores

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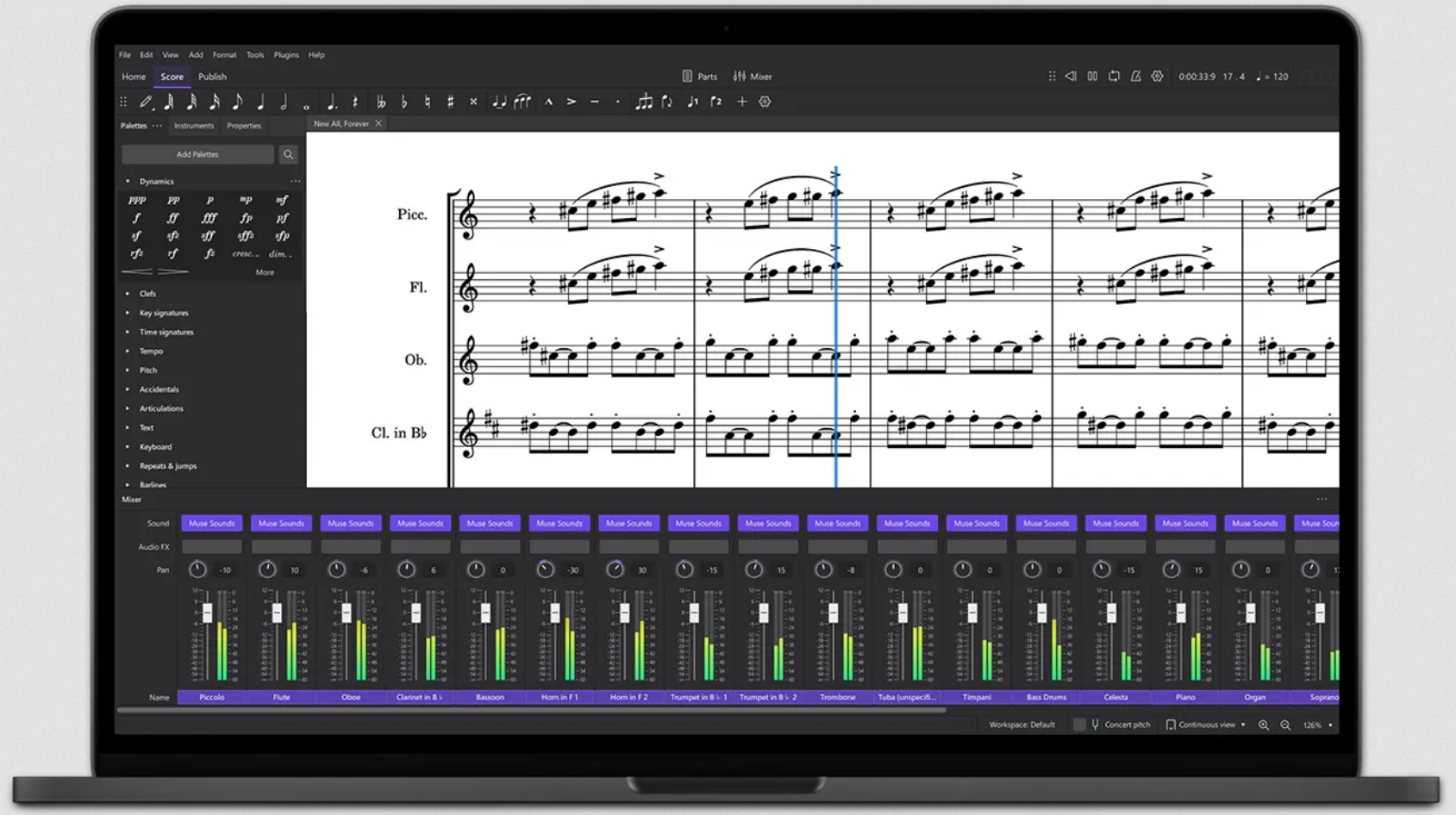
Editing rhythms in graphical user interface...



Tedious to enter the rhythm for each note.

Editing rhythms in Lilypond...

```
  d r |
  c4 es,8 es es4 d8( c) |
  % bar 115
  bes'2 d |
  f4 es,8 es es4 d8( c) |
  bes'2 d |
  f1 |
  bes,2 r |
  \bar "|."
}

violinoTwoMusic = \relative c' {
  \globalOne
  d8 |
  d d r d d d r d |
  bes' bes4 a8 bes( d,) r bes' |
  a a r a a a r a |
  f c'4 bes8 a( f) r f' |
  % bar 5 (5 and 6 same in Vln. II)
  g16 a,( bes) g' f a,( bes) as' g d( es) as g es( g) bes |
  a b,( c) a' g b,( c) bes' a e( f) bes a( c) a( f) |
  d8( d) c( c) bes r bes( bes) |
  d,( f') a,4\trill bes16( d) c( a) bes( d) c( a) |
  f8( bes) c( c) bes r bes( bes) |
  % bar 10
  d,( f') a,4\trill bes r |
  R1 |
  bes8( bes) bes( a) bes4 r |
  R1 |
  f8( c') d( c) a4 r8 c |
  % bar 15
  d16 e,( f) d' c e,( f) es' d a( bes) es d( g,) d'( f) |
  e fis,( g) c d fis,( g) d' e b( c) f e( g) e( c) |
  f a,( bes) g a( c) d( bes) c( a) bes( g) a( c) d( bes) |
  c8 bes4 g8 a( f) a( c) |
  d16 e,( f) d' c e,( f) c' bes fis( g) bes d fis,( g) bes |
  % bar 20
  e8 f e4\trill f r |
  R1 |
  r2 d8 g,4( fis8) |
  g( g) g( g) g( g) fis( fis) |
  g4 r r2 |
```

Tedious to enter the rhythm for each note.

Editing rhythms in ABC...

```
X: 3
T: Amazing Grace
R: waltz
M: 3/4
L: 1/8
K: Dmaj
V:1  Ad|"D"d4 fe/d/|"D"f4 fe|"G"d4 B2|"D"A4 Ad|
V:2 d2|A4 dB/A/|d4 AB|B4 d2|f4 df|
V:1 Bm"d4 fe/d/|"E7" f4 ef|"Asus" a6|"A/G"a4 fa||
V:2 f4 dB/A/|B4 Bd|d6|c4 df||
V:1 "D"a4 fe/d/|"D"f4 fe|"G"d4 B2|"D"A4 Ad|
V:2  f4 dB/A/|d4 AB|B4 d2|f4 df|
V:1 "Bm"d4 fe/d/|"E7"f4 "G/A"e2|"D" d6|"D"D4||
V:2 f4 dB/A/|B4 G2|F6|F4||
```

Tedious to enter the rhythm for each note.

Our contribution

- A language called *abcd* closer to a real graphical score
  $\rightarrow$ Musical language like *Markdown*

- Easy to read
  $\rightarrow$ Rhythm is only *partially specified*

`https://github.com/francoisschwarzentruber/abcd`

demo

Outline

Problem definition

```
4/4 a.       b |
```

Definition (Rhythm inference)

- input:
  - approximative durations $\hat{\delta}_1, \ldots, \hat{\delta}_n \in \mathbb{R}^+$, $\hat{\delta}_1 = 5,\ \hat{\delta}_2 = 1$
  - finite domains $\Delta_1, \ldots, \Delta_n \subseteq \mathbb{R}$,

    $\Delta_1 = \{3/2, 3/4, 3/8, 3/16, 3/32, 3/64\}$

    $\Delta_2 = \{1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64\}$
  - duration T of a measure; $T = 1$
- output: inferred durations $\delta_1, \ldots, \delta_n$ that form a solution of...
  a the mathematical program we are going to define!

  $\delta_1 = 3/4,\ \delta_2 = 1/4$

Outline

Consistency

$$\delta_i \in \Delta_i \text{ for all } i = 1..n \tag{1}$$

$$\sum_{i=1}^{n} \delta_i = T \tag{2}$$

Taking the approximate durations into account

$$\begin{array}{l} \text{minimize } \sum_{i,j=1}^{n} err_{ij} \\ \left\{ \begin{array}{l} \delta_i \in \Delta_i \text{ for all } i = 1..n \\ \sum_{i=1}^{n} \delta_i = T \\ \delta_j - \delta_i \leq err_{ij} \text{ if } \hat{\delta}_i \geq \hat{\delta}_j \\ err_{ij} \geq 0 \end{array} \right. \end{array}$$

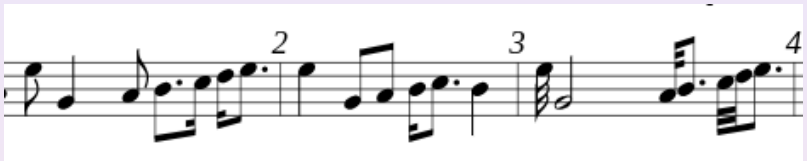
Technical trick

It is then transformed into a Mixed-Integer linear program by:

- introducing variables $x_{id} = 1$ for all $i = 1..n$, for all $d \in \Delta_i$
- adding the constraint $\sum_{d \in \Delta_i} x_{id} = 1$: δ_i takes a unique value
- replacing each occurrence of δ_i by $\sum_{d \in \Delta_i} d \times x_{id}$.

Outline

Future work: modeling



- Improving the inference

  $\rightarrow$ Improving the model

- Take the existing score into account

  $\rightarrow$ Automatically take a previous rhythm in the score

Future work: algorithmic questions

- Some input, e.g. `4/4 a b c |` may have several solutions
  → Minimize the number of rhythm indication to add for having a unique solution

- Some input, e.g. `4/4 a4 b4 c2 |` are over specified
  → Remove a maximum number of rhythm indication to still have this very unique solution

- Need for real-time, need for an efficient algorithm
  → Study theoretical complexity? Design efficient algorithms?

Future work: development

- Improve the tool
- Integrate this feature in Musescore and/or Lilypond and/or ABC?

Other ideas

- Link with type inference in programming language?
- Preferences? Default reasoning?
- Data mining to the most frequent rhythms?

- Thanks to Charlotte Truchet
- Thanks in advance to the potential group of students working on that project

and

Thank you!