

Figured Bass Encodings for Bach Chorales in Various Symbolic Formats: A Case Study

Figured bass (FB) is a type of music notation that uses numerals and other symbols to indicate intervals to be played relative to a bass note (Williams and Ledbetter 2001). FB was commonly used in Baroque music, and served as a guide to keyboards, strings, and other instruments improvising the *basso continuo* accompaniment. Not only does FB serve as a guideline for performers, it also reveals insights into the chords and harmonic rhythm intended by composers, beyond what is readily available in the notes themselves.


The computational study of FB remains an under-researched topic, likely due to the lack of machine-readable datasets annotated with FB. This is unfortunate, as FB data can be of interest to a broad audience, in areas including performance, research, and pedagogy.

This paper is intended to address the paucity of digital FB data by 1) investigating procedures for systematically annotating symbolic music files with FB, and 2) producing and releasing a model annotated dataset as an illustration of how these procedures can be applied in practice. We chose Johann Sebastian Bach's four-voice chorales as the focus for this case study, as they play a key role in modern pedagogy, and are of significant historical importance.

1. Encoding Figured Bass

Despite its seeming simplicity, encoding FB is not a trivial task. This section investigates (A) the extent to which musicXML, ****kern**, and MEI support FB, and (B) how well FB annotations are preserved when translating from one symbolic format to another.

Although the majority of FB consists only of numerals and accidentals, our examination of the Bach chorales in the Neue Bach Ausgabe (NBA) critical edition (Bach et al. 1954) revealed three additional types of notation:

- (1) figures with slashes (augmented or diminished intervals), e.g.: \times
 - (2) figures with continuation lines (prolongation of the harmony), e.g.: 5_____
 - (3) multiple figures over a stationary bass, e.g., 6–5 over the same bass note: 
- 6 5

We chose BWV 33.6¹ as the basis for a case study on how well these types of notation can be encoded and translated, as it contains all three of these elements. We used MuseScore (v.3.3.2) to encode² the FB in musicXML,³ and a text editor to encode the ****kern**⁴ and MEI.⁵ No problems were encountered encoding but there were some issues translating between the three formats.

In general, the standard FB notation (numbers and accidentals) were properly preserved when translating between the three file formats, except for MEI to musicXML or to ****kern**, where all FB information was lost in both cases. There were also some additional issues with the

¹ The Neue Bach Ausgabe (NBA) critical edition (Bach et al. 1954) was used for FB encodings.

² All the encoded symbolic files are available at:

https://github.com/juyaolongpaul/Bach_chorale_FB/tree/master/FB_source. We chose GitHub because of its capability of version control.

³ FB encoding instructions for musicXML: <https://musescore.org/en/handbook/figured-bass>.

⁴ FB encoding instructions for ****kern**: https://doc.verovio.humdrum.org/humdrum/figured_bass/.

⁵ FB encoding instructions for MEI: <https://music-encoding.org/guidelines/v4/elements/fb.html>.

three special types of notation introduced above as shown in Table 1 and described in more detail below.

Table 1: The results of the file translation for special cases.

The first column indicates the original format, and subsequent columns indicate target formats. We examined the FB elements (1) to (3) mentioned above. The first row of each cell indicates the software used for the translation (Nápoles et al. 2019). “Yes” means the translation was successful.

| | musicXML | **kern | MEI |
|----------|---|--|--|
| musicXML | | <i>musicxml2hum</i> (1): yes (2): no (3): yes | <i>Verovio</i> (1): no (2): no (3): no |
| **kern | <i>hum2xml</i> (1): no (2): no (3): no | | <i>Verovio</i> (1): yes (2): yes (3): yes |
| MEI | <i>music21</i> (1): no (2): no (3): no | <i>mei2hum</i> (1): no (2): no (3): no | |

*MusicXML to **kern (musicxml2hum⁶):* (2) the continuation line could not be translated, and the resulting **kern file had syntactical errors. Translations worked for chorales with no continuation line.

MusicXML to MEI (Verovio⁷): (1) accidentals and slashes were all missing; (2) continuation lines were missing; (3) although all figures were preserved, they all shared the same “tstamp” value, which should be different.

***kern to musicXML (hum2xml⁸):* (1) slashes were not translated properly, including (2) continuation lines, and (3) figures over a stationary bass were partially lost. The reason is that FB is translated as lyrics, rather than the “<figure-bass>” tag musicXML natively supports for FB encodings.

***kern to MEI (Verovio):* (1) although “6” with backslashes were correctly translated they could not be rendered properly using Verovio.

*MEI to musicXML (music21⁹) and MEI to **kern (mei2hum¹⁰):* all FB information was lost.

⁶ <https://github.com/craigsapp/humlib>

⁷ <https://github.com/rism-ch/verovio>

⁸ <https://github.com/craigsapp/humextra>

⁹ <https://github.com/cuthbertLab/music21> (v. 5.1.0)

¹⁰ <https://github.com/craigsapp/humlib/>

2. Bach Chorales Figured Bass Dataset (BCFBD)

We present BCFBD, a dataset we constructed containing FB encodings in musicXML, **kern, MEI, and MIDI formats for 103 Johann Sebastian Bach chorales.¹¹ We began with an existing **kern edition (Condit-Schultz et al. 2018), which is based on the fourth printed edition of the 371 chorales by Breitkopf & Härtel (1870) and does not contain any FB. We automatically translated the music from **kern into musicXML with music21.¹² Of the 371 chorales, we manually added FB encodings to 103 chorales with FB indicated in the NBA edition¹³ using MuseScore (v. 3.3.2). We also made some changes to match the NBA edition such as transposing, changing the meter, pitch, and duration of certain notes, and adding a fifth voice. Finally, we added editorial notes¹⁴ when the FB was incomplete or inaccurate, so that users could compare with the original FB.¹⁵

We also used our findings from Section 1 to produce FB encodings for other symbolic formats. We started with our master musicXML files, and translated them into **kern files, with minor manual corrections to the chorales with FB continuation lines. We then obtained MEI files from the **kern files. Finally, we produced¹⁶ MIDI files as well. This diversity of symbolic formats offers researchers the opportunity to use the format best suited to their preferred software.¹⁷

We hope that BCFBD will facilitate computational studies, such as comparative studies on the temporal development of Bach’s FB and harmonic organization, and that it will be of use for applications such as teaching computers to arrange FB for unfigured chorales.

In the future, we will focus on adding symbolic encodings (musical content and FB) for Bach chorales beyond the 371 Breitkopf & Härtel edition,¹⁸ with the goal of producing a comprehensive symbolic dataset of Bach chorales.

¹¹ The complete reference table is available at:

https://github.com/juyaolongpaul/Bach_chorale_FB/blob/master/reference_table.xlsx.

¹² We asked a music theorist to compare the translated musicXML against the original **kern, and found no significant differences in musical content. The reason why we did not use music21 to translate **kern into musicXML in Section 1 is that music21 will lose all the FB information.

¹³ Eight of the 111 chorales were omitted for encoding reasons (instrumental interlude chorales, two-voice chorales, and bass independent chorales), and will be treated in a later phase of our project.

¹⁴ Editorial figures are saved in the “.mscz” file format.

¹⁵ Chorales with original figures were saved as musicXML.

¹⁶ Using music21 (v. 5.1.0) to export musicXML files to MIDI.

¹⁷ If only one format were offered, but is not supported by a given piece of research software, then it would need to be converted to the format supported by the software, which could lead to a loss of FB information, as discussed above.

¹⁸ There seem to be 69 extra chorales attributed to Bach: <http://www.bach-chorales.com/ChoralesNotInRiemenschneider.htm>

References

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