Digital Critical Editions of Music:

A Multidimensional Model

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Abstract

This paper describes the limitations of critical editions of music in book format, and presents an abstract, generic model for digital critical editions to overcome these limitations. Such an edition can be imagined as a collection of digitised and enriched source materials, modelled in a multidimensional space. At the user's request, two-dimensional slices through this space are generated that may correspond to certain stages in the work's transmission history or to an editor's interpretation of the work, or they may visualise the transmission process itself. Four case studies illustrate this model and indicate how it may help solve problems encountered in traditional scholarly editions. Unlike in literary studies, the implications of ICT developments for critical editions have hardly been debated in musicology. This paper is also meant to serve as a starting-point for such a debate.

Introduction

The aim of this paper is to think through some implications that ICT may have for critical editing and scholarly editions of music. These implications are likely to go far beyond currently accepted practices such as the use of music notation software for the preparation of scores, the online distribution of music in PDF format, or even the

interchange of score data in some encoded format. Yet there is an almost complete silence as to the more radical possibilities for innovation. This is rather surprising, perhaps even worrying, since the 'critical edition in the digital age' has been an issue of debate for at least ten years in literary studies (Breure *et al.* 2004, 39-45) and musicologists are generally well aware of developments in that area. So why this silence? Are musicologists disappointed by ICT after so many failed promises? Is current technology not mature enough for digital critical editions of music? Or is there no perceived use for these?

Outline

It is mainly the last question that will be addressed in this paper. To prepare the ground, we will examine editorial methods in literary studies and musicology. Then we will present a generic, multidimensional model for digital critical editions of music, which is illustrated by means of four case studies. The paper finishes with a critical evaluation of the model and a discussion of some obstacles that must be overcome before digital critical editions of music will be routinely created and used by musicologists.

What this paper is not about

This paper describes an abstract model for multidimensional editions of music as finished, relatively stable applications. Two issues are specifically not addressed: the implementation of such editions, and the process whereby editors might create them. As part of the former, a solution for the encoding of textcritical features was proposed by Wiering *et al.* (2005a); the latter was briefly discussed by Wiering *et al.* (2005b). It is also important to note that the case studies in this paper are conceptual and do not

describe current initiatives for creating digital critical editions, with the exception of the Electronic Corpus of Lute Music (ECOLM).

Literary studies

By tradition, the object of a scholarly edition is to establish a well-reasoned text of a document. Methods for doing so have been around for centuries. The most influential of these is the stemmatic method developed by Karl Lachmann in the early 19th century (Grier 2001). Its aim is to reconstruct, by comparing the surviving sources of a text and by evaluating their differences, the archetypal document from which these sources descend. Since Lachmann's days, many alternative approaches have been proposed; all of these combine one or more reconstructed texts with an account of the source network. An important part of the latter is the critical apparatus, a list of corrected errors and variant readings that have not made it to the final text.

Three technological developments, structured markup, hypertext and mass digitisation, have fundamentally affected critical editing. Structured markup became virtually identical with SGML after 1986, when it was released as an ISO standard; it is now superseded by the closely-related XML recommendation. Document encoding using structured markup has two important characteristics that distinguish it from desktop publishing formats (and flat text representation). First, it separates the logical structure of a document from its visual presentation. As a consequence, multiple 'views' can be generated from one encoded document. For example, one view of a book is its full-text content, another the table of contents. Second, it allows the document to be enriched with additional information. An example is the encoding of both source errors and their correction, so that an apparatus can be automatically created. Both features of structured markup are exploited in the TEI markup scheme, which is used successfully

in many digital edition projects that focus on the information contained in the edited documents.[1]

Hypertext, which first reached the general public through Apple's HyperCard (released in 1987) and later through the World Wide Web, allows documents to be structured in a non-linear way. A hypertext edition therefore may present more than one reading of a text, presenting alternative continuations of a text where the sources differ, or co-ordinate a number of completely encoded sources of a single document. McGann's notion of HyperEditing, briefly discussed below, provides a theoretical justification for such an approach.

Mass digitisation arose in the 1990s, stimulated by the ever decreasing prices of storage space and by the availability of standard technology for creating and processing digital audio, images and video. A large number of digital libraries, archives and museums have emerged over the last decade, giving scholars access to documents with unprecedented ease. Even though metadata are routinely attached to digitised sources, their content is still undigested: therefore they provide no alternative to critical editions. However, models for digital editions do often include digital facsimiles as a way of presenting the raw materials on which the edition is based.

HyperEditing

From the many scholars who have examined the consequences of these developments for critical editing, we have singled out Jerome McGann (1995) for particular discussion because he draws the attention to the limitations of the book format itself: a book cannot contain and co-ordinate all source materials that an edition is based on. The analytical

[1] An example in musicology is *Thesaurus musicarum italicarum*, which contains nearly 30 Italian music treatises edited with TEI markup (http://www.euromusicology.org)

tools an edition in book format contains, notably the critical apparatus, are shaped by this fact: these abbreviate and restructure information from many different sources in such a way that it fits the book format (see Figure 1a). The price one pays for this in terms of usability is quite high. For example, it is hard to reconstruct a primary source from editorial text and the evidence in the apparatus, and virtually impossible to get a full picture of the source network. Another issue McGann raises is that the book format does not allow the inclusion of non-textual information such as performances of a play or song, or even the physical features of a source.

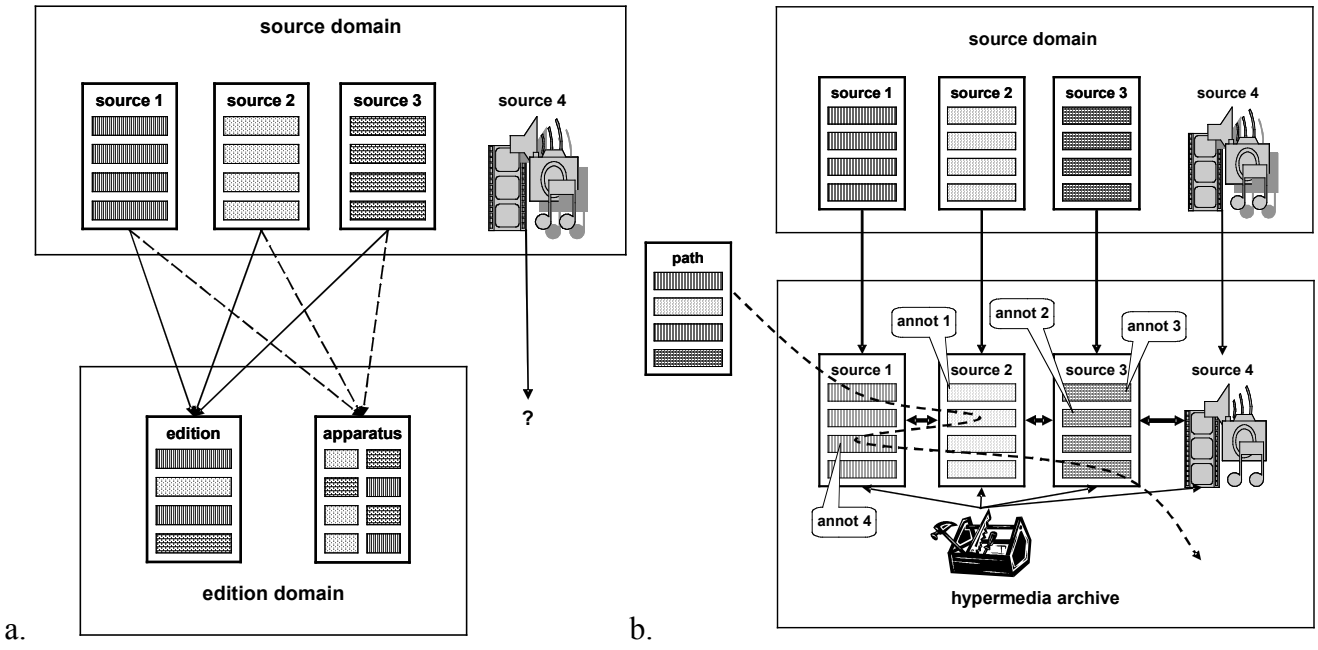


Figure 1. Different models of editing. a: editing in book format; b: HyperEditing

The solution McGann proposes is HyperEditing, the creation of critical, fully networked hypermedia archives. This concept is illustrated in Figure 1b. A critical archive consists

of virtual copies of the sources, connections between these, annotations with critical and contextual information, and analytical tools for searching and comparing the materials.

As a networked model, the critical archive documents the genesis, transmission and reception of a text through the material instances by which it survives. It is not a hierarchical model that aims at a reconstruction of the author's intention. Yet such a reconstruction can be incorporated into the model, for example by defining an edition as a 'reading path' through the critical archive. (A related notion of reading path can be found in Kress (2004) and Darnton (2005).)

HyperEditing deals with material instances of texts rather than with idealised works abstracted from those instances. This seems a promising perspective for musicological editing, especially if one considers written sources as instructions for – and often the only remaining traces of – past performances.

Critical editing in musicology

Critical editing in music has been shaped after traditional models of literary editing (Grier 2001). In music too, the task of the editor is to establish the text of a composition by some accepted method, whether this is by means of a stemmatic, best-text or copy-text approach. (From here on 'text' is short for the 'musical text' of a composition.) This text is then transcribed or adapted to modern notational conventions, so that it is easily legible. Missing information is supplied (e.g. text underlay) and perceived ambiguities are resolved (e.g. *musica ficta*). All of this makes critical editions usable in performance. At the same time expert performers and scholars may feel that such adaptations add an unwanted layer of interpretation to the work. Transcription and the level of editorial intervention are therefore much more an issue of debate than how to establish the composition's text.

Philip Brett (1988) observed that there are very few successful applications of the stemmatic method in music. The fundamental problem here is the meaning and weight one attaches to variants that occur between sources of the same work. Text-based editorial methods tend to treat variants as corruptions, whereas in fact they may often reflect adaptation to performance circumstances. To take Brett's argument one step further, to create an edition as a reconstruction of the 'work itself' and not to give full access to the 'instances' that together constitute this work is to misrepresent the inherent flexibility and adaptability of a very large repertoire of music.

Music publishing has been strongly affected by ICT, but mainly at a practical level. Scores prepared using music notation software are routinely distributed via the Internet. A large number of choral works in decent, practical editions is available through the Choral Public Domain Library (http://www.cpdl.org). At the scholarly end of the digital publication spectrum stands a website containing diplomatic transcriptions of the works of the 15th century composer Caron (http://www.une.edu.au/music/Caron). Other examples of the influence of mass digitisation include a range of conventional digital library projects such as Variations 2 (http://variations2.indiana.edu) and more advanced ones such as the Digital Image Archive of Medieval Music (http://www.diamm.ac.uk), which features digital restoration of scanned images, and the Online Chopin Variorum Edition (Rink (2006); http://www.ocve.org.uk), where sections from different sources can be aligned and compared.

Apart from the last example, hypertextual editions of music do not seem to exist yet, but structured markup has reached music in several ways. An important early example is Standard Music Description Format (Newcomb 1991). SMDL distinguishes

four domains in which a composition exists: visual (score), gestural (performance), analytical and logical. The last abstractly represents compositional intent, for which SMDL defines an SGML vocabulary. SMDL was never implemented except in a few demo's, but conceptually it influenced several XML-based music encoding systems. The best known of these is MusicXML (Good 2001; http://www.recordare.com). Its purpose is to allow interchange of musical data, particularly between music printing applications, and has many facilities for precisely recording layout. The Music Encoding Initiative is less detailed about layout, but has some basic textcritical structures (Roland 2005).

Some attempts have been made to provide deeper access to the materials from which an edition is created. Thomas Hall (1975) experimented with computer-based stemmatics for the New Josquin Edition, but here has been no follow-up to his experiments. Standard databases can be effectively configured for storing musical variants, as Yo Tomita did in his studies of J.S. Bach's WTC II (Tomita and Fujinami, 2002). A drawback to this approach is that the information is logically separated from the score. Experiments in integrating the two, using a TEI-based tagset, have been done as part of ECOLM (http://www.ecolm.org). The separation of logical structure and visual presentation, is especially exploited in the *Corpus Mensurabilis Musice Electronicum* (Dumitrescu (2001); http://www.cmme.org). Out of one encoded score, different transcription styles can be generated: one can for example choose between original and modern clefs, and different barline styles. CMME will also provide access to variants and manuscript context of works.

A multidimensional model

We perceive several open issues problems in current methods of critical editing of music:

- the unclear distinction between establishing the text of a composition on the one hand and transcription style and supplying performance information on the other;
- loss of information about the original notation;
- the contribution of variants to the understanding of a musical work;
- the usability of textcritical data, particularly when the context from which it is abstracted matters.

All of these relate to the limitations of the book format as a visual, static, two-dimensional representation of a composition. As in literary studies, a HyperEditing approach might offer some solutions for music too. This is the purpose of the multidimensional model that is proposed in this paper and illustrated in Figure 2.

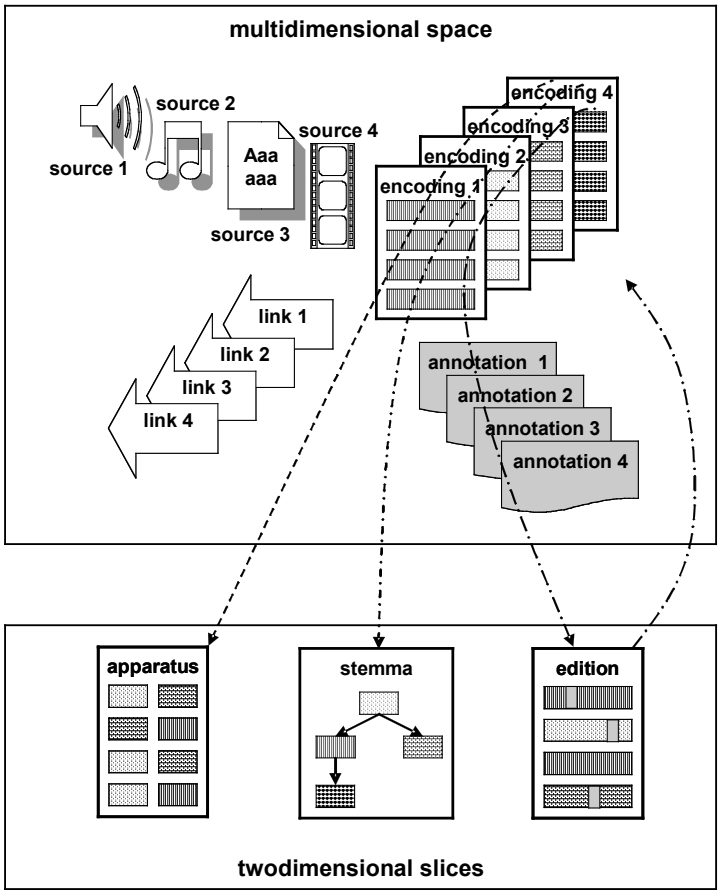


Figure 3: multidimensional model for a digital critical edition of a composition.

A digital critical edition of music may ideally consist of the following, interconnected components:

- digitised sources, from any relevant medium: usually these will be score facsimiles, but video and audio recordings are explicit options;
- source encodings, making the information content of the sources suitable for computer processing;
- annotations; categories include textcritical features, inferences (e.g. related to performance), musicological knowledge;

- links to related works.

Such a collection of information can be imagined as a multidimensional space, in which different categories of information each occupy a different axis. For example, in addition to the two dimensions of the score, one can imagine versions, emendations, adaptations to performance and compositional features as additional dimensions to the edition. These are not so much meant as dimensions in a mathematical sense, as to suggest ways of accessing the edition, for example by projecting information onto a plane or by taking two-dimensional slices from it. Examples of such views are a diplomatic or emended transcription of a source, an apparatus, a stemma, or an edition conceived as a reading path through sources and annotations. At least as important is the possibility of switching views, for example from an apparatus view of a particular passage to the context in which it appears in a source, or – when multiple works are edited in this way – from a collection of similar features to the works in which they appear. Users can contribute to the edition by adding their own views and annotations.

Quite a sophisticated set of tools will be needed to realise these possibilities – but a discussion of these falls outside the scope of this paper. The music representation these tools will work on has one important requirement which distinguishes it from the ones mentioned above. It is not a representation of the musical surface of a finished product (Wiggins 2006, 4.2), nor one of the musical logic that underlies it; instead it represents ideally all the information contained in the source that is necessary for deriving, whether by computer or human intelligence, meaningful views of the composition.

Two examples may illustrate this:

- Logically, CMN orders notes in bars of a predictable length, demarcated by barlines; so notes can be represented as the content of a bar, and barlines need not be explicitly indicated. When encoding a source, one can generally not assume that the length of the bar is predictable or correct, or even that a barline has the function it has nowadays. A non-hierarchical representation of the source *text* is therefore needed.

- Likewise, CMN has clear rules for accidentals, which make it possible to represent the accidental as part of the pitch of a note. In mensural notation, it is not always clear to which note(s) an accidental should be applied, so it should be represented separately.

The requirement is thus that the input to the edition, the notational, visual and possibly material aspects of the sources, is represented; editorial decisions about their meaning belong to a layer of inferences that comes on top of the source representation. Formats that encode the 'logical content' of a work are unhelpful for supporting the editorial process, which also follows from the fact that, if such a thing as the logical content of a composition exists at all, that the task of the editor is to *establish* the logical content rather than to assume its existence.

It is important to note that the model, even though it is presented as an abstract and generic one, simplifies reality. This is especially important at the representation level. Minute details of ink and damage can sometimes lead to fundamental decisions

about the editorial text of a composition, but this does not mean that such details must be routinely encoded. There will always be a negotiating process between simplicity and comprehensiveness, aimed at reaching an optimum effectiveness. Therefore each repertoire will require its own specific representation. At the same time, to allow interchange, it should conform to the requirements formulated in Wiggins (2006). The simplification inherent in modelling also explains why the model includes a digital facsmile: it puts a lower boundary on the level of detail of the encoding, and it allows an immediate check for problems and ambiguities in the source that may have been left unencoded.

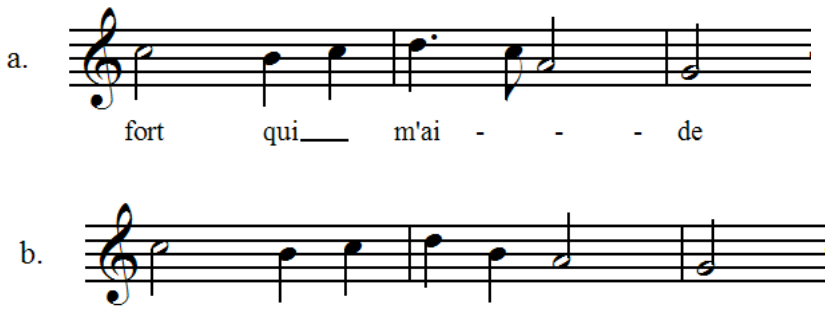
The multidimensional model solves the issues mentioned at the beginning of this section by giving full access to as many source representations as one needs, by defining an edition as an adaptive layer on top of the sources, and by offering flexible generation and presentation of textcritical information. The model also raises a number of new questions. How can the model be realised in practice, which dimensions does it contain and useful is it? The following four case studies will help finding some answers to three of these.

Case studies

Ma bouche rit: anonymous mass and Ockeghem's chanson

An anonymous Missa *Ma bouche rit* survives in the early 16th-century manuscript VienNB 11883 (fols. 285v-294r). It is remarkable for its exceptional treatment of the model on which it is based: all three voices of Johannes Ockeghem's chanson are used as *cantus firmi* in at least one of its movements (Olive 2003). If these *cantus firmi* are compared to Wexler's edition of the chanson (Ockeghem 1992), there appear to be more

than 10 consistent differences that affect pitch and/or rhythm, one of which is shown in Example 1.



Example 1a: Ockeghem, *Ma bouche rit*, superius bars 40-42, after Ockeghem 1992; b: Missa *Ma bouche rit*, superius bars 40-43. All note values quartered.

Obviously, the mass is not based on this reading of *Ma bouche rit*, which is a 'best text' edition derived from the manuscript PNiv (Ockeghem 1992, p. lxxviii). As seventeen sources of Ockeghem's chanson survive, one wonders if another one has a closer relation to the mass. The key to the answer is the edition's apparatus, a fragment of which is shown in Figure 3.

39/1-2 bl sbr, bl m (*MunSche*); 41/1-2 mi col (*BerGlo, Cop 1848, Dij, FBNC 176, FR 2356, MunSche, NHMel, PBN 4379, PCord, PPix, RCG XIII.27, WLab, Wol 287*); 41/2 c fu, b fu (*RISM 1538*[9]); before 42/1 sharp (*NHMel*); 42/3-43/2 bl sbr,

Figure 3, Fragment of apparatus for Ockeghem, *Ma bouche rit*, after Ockeghem (1992, lxxx); line breaks shown as in original.

First, this fragment demonstrates three reasons why it is hard to use an apparatus: it presents source data outside the context of the score, it uses a specialised 'code' for these data and it breaks the connection between data from a single source. Second, it appears that the variant from Example 1 does not occur elsewhere. In total, the mass contains at least five variants that make musical sense but are not known from any of the chanson's sources.[2] It is unlikely that these are Ockeghem's, but they are surely relevant to a study of the transmission and reception of the chanson.

The principal contribution of a digital critical edition of Ockeghem's chanson would be to allow direct access to the sources through a third dimension of the edition, rather than indirect access only, through the apparatus. A second contribution would be to be able to upload a new source (or reconstruction of a source) to the existing edition. Finally, the mass (and other arrangements of *Ma bouche rit*) could be linked to the edition in such a granularity the user can see how these relate to the model.

J.S. Bach, Mass in B minor

[2] A complete reconstruction of the model is available at http://www.cs.uu.nl/people/fransw/

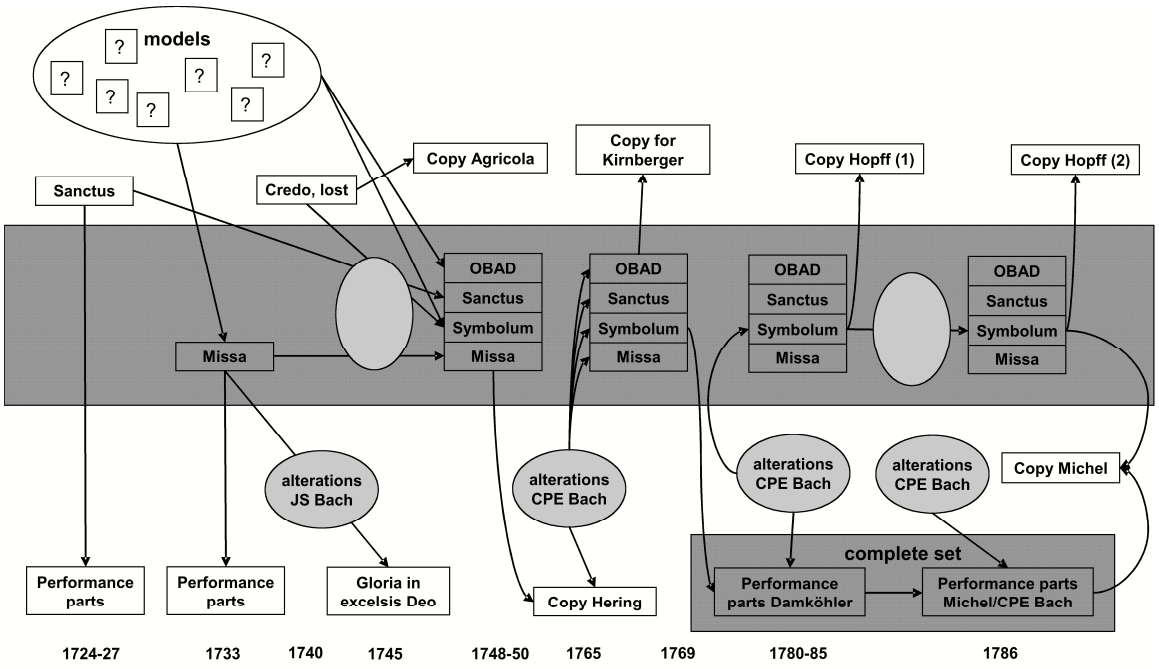


Figure 4: J.S. Bach, Mass in B Minor (BWV 232), relationships between sources, with approximate dates. OBAD: Osanna, Benedictus, Agnus Dei and Dona nobis pacem.

J.S. Bach's Mass in B minor (BWV 232) has a very complex source situation, the bare outlines of which are shown in Figure 5 and discussed below after Butt (1991), Wolff (Bach 1997) and Rifkin (Bach forthcoming). Bach commenced work on the autograph score in 1733. The work at that stage consisted only of the 'Missa', a Kyrie and a Gloria. Most of its twelve movements are parodies from cantatas, but not all models survive. A set of mostly autograph parts from 1733 also survives, adding a level of performance detail that is missing from the score. These parts were never altered, unlike the score, which was subjected to a series of additions and revisions. The most important of these took place in 1748-50, when Bach expanded the Missa into a complete Mass. Again, most movements were based on earlier works: the Sanctus of 1724, a Credo intonation of c. 1740 and numerous cantata movements. The *Confiteor*

and possibly the *Et incarnatus est* were newly composed. There are many signs of revision for all movements including the Missa. Due to his failing eyesight Bach also introduced a number of errors, particularly in the Sanctus. After Bach's death the manuscript passed to his son Carl Philipp Emanuel, who added several layers of alterations. The first of these correct apparent errors and improve legibility; later ones are connected to a performance of the *Symbolum Nicenum* (the movements setting the Credo text) in 1786. Several sources that derive from the main manuscript reflect earlier stages of the manuscript and may therefore be used to distinguish between layers of alteration. The most important of these are the cantata *Gloria in excelsis Deo* of 1745, a copy of the Mass in J.F. Hering's hand (c. 1765), one made for J.P. Kirnberger in 1769, and a set of parts (containing an earlier and a later layer) and several scores of the *Symbolum Nicenum* dating from the 1780s.

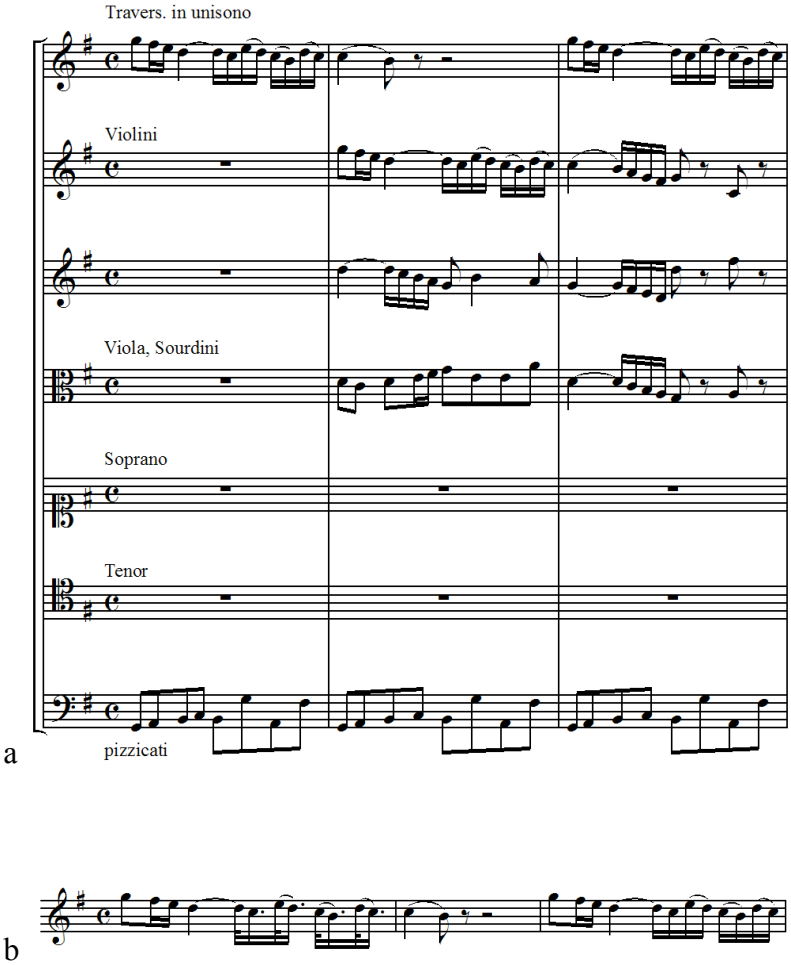
At least three possible strategies for editing the complete Mass emerge from this overview. One is to reconstruct the score as Bach left it at his death and emend it only where it is in error. Another is to construct an 'optimum text' by selecting the musically most satisfactory variants from the score, the 1733 parts and possibly also from the models of the movements. The third is to focus on performance and add to the score as it was in 1750 the kind of detail that the parts written in 1733 and 1786 offer. Every consecutive strategy involves a larger number of subjective decisions than the preceding one, but at the same time represents an equally legitimate view of the same underlying source materials. A multidimensional edition of the Mass would therefore represent the information content of the sources and allow a range of different views to be generated from these. Note that it is not the purpose of our model to enforce a particular editorial

method: the only requirement is that an edition is a view on the source materials, no matter how and why it is created.

A well-known problem in the *Domine Deus* may illustrate this position (for the details see Herz (1975)). Example 2 shows the beginning of the movement, in which the main instrumental motive is played first by the two flutes and then by the first violin. The 1733 parts however indicate performance by flute 1 only; moreover the first bar of the flute is notated with a different rhythm, which reappears in second violin and viola, bar 27, but nowhere else. Three questions emerge from this situation:

- what does this variant indicate, (an approximation of) a rhythm, a reinforcement of the articulation, or both?
- how should other appearances of the same motive be treated, for example first violin, bar 2?
- what is its relevance to the scoring and performance of the final version of the work?

The answers to these questions influence an editor's rendition of the passage, but as important as the editorial decision is the access to the evidence. One might even claim that the variants together convey a better understanding of this movement than an editorial to present a single solution.



Example 2. J.S. Bach, *Domine Deus*, bars 1-3 from Mass in B Minor (BWV 232); a. after manuscript score and b. flute 1 after 1733 parts.

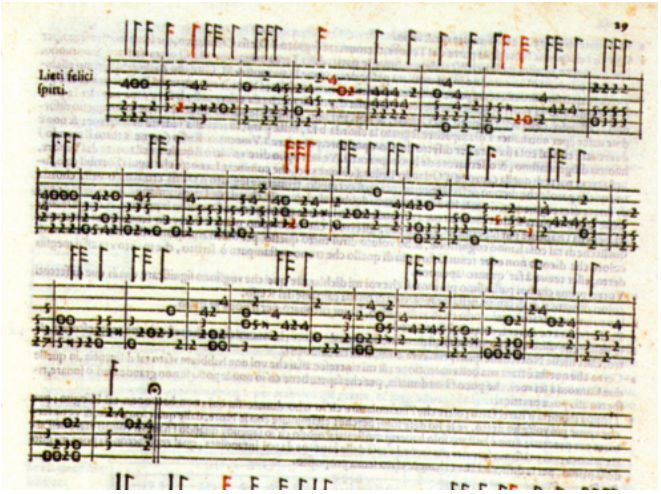
In addition to offering a range of possible views of the 'text' of the work, the added value of a digital critical edition is to give direct access to the underlying evidence. An exploration of the work could start from an overview such as in Figure 4,[3] to which the user could zoom in at the required level of detail, along different dimensions: sources, source layers, relations to models, editorial preferences and emendations, visual presentations and recordings. It is only natural that in such an environment a user would

[3] An animated version of the overview is available at http://www.cs.uu.nl/people/fransw/

like to contribute annotations or to create his/her own view of the work. Thus, the distinction between user and editor begins to fade, and a concept of editing as an ongoing, collective process emerges (Robinson (2002) makes the same observation for textual editions). Especially in complex cases such as Bach's Mass this seems an attractive mode of operation, as there is so much evidence involved that it is an almost superhuman task for a single researcher to collect it from scratch and to digest it into a finished product.

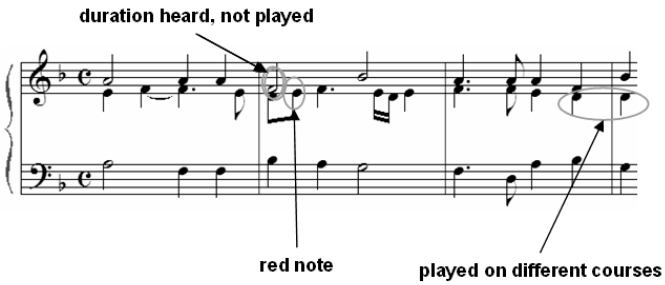
V. Galilei, Fronimo

This case and the next one are based upon practical experiments for the ECOLM project. The aim of ECOLM is to make sources of lute music accessible to scholars, lute players, and others. Accessibility means more than just displaying the edited content of the sources. Since the sources employ a specialist form of notation, tablature, they are virtually inaccessible to non-players, including musicologists. Transcription to CMN or sound is not just a nice extra but an essential property of such an edition for giving this relatively neglected repertoire its proper place in music research. However, such transcription involves both addition and loss of information.



Example 3. V. Galilei, *Fronimo*, Lieti felici spiriti, facsimile

Example 3, taken from Vincenzo Galilei's lute treatise *Fronimo* (1568), illustrates this. The principle of French and Italian lute tablatures is to indicate the moment on which certain frets must be stopped and certain courses (i.e. string or pair of strings) must be struck. Durations and voices are not indicated, and neither is pitch spelling. Therefore, a polyphonic transcription, such as the one shown in example 4, requires a great deal of editorial inference, sometimes even involving durations that are physically absent but plausibly supplied in the listener's mind. At the same time, precise instructions about frets and courses, which influence timbre, are lost.



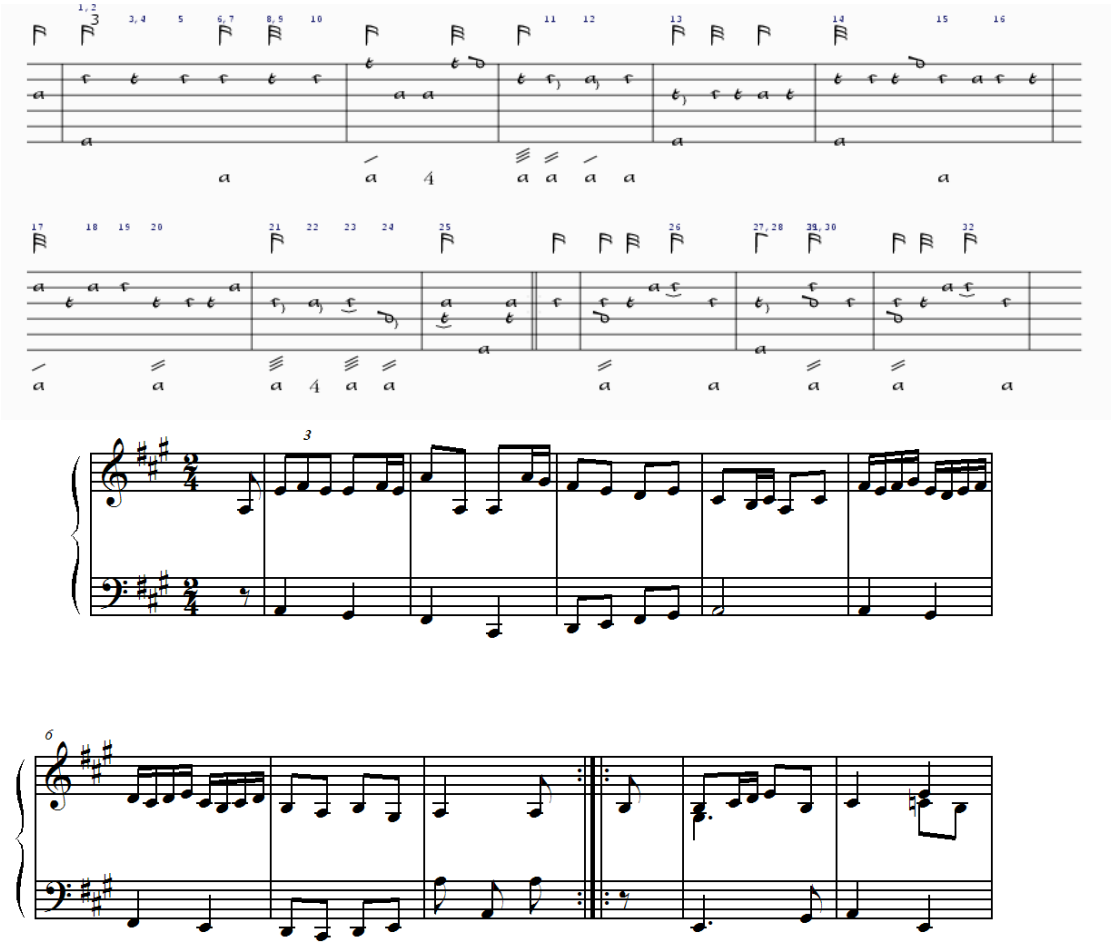
Example 4. V. Galilei, *Fronimo*, Lieti felici spiriti, transcription bars 1-4

This particular composition from *Fronimo* also gives a dramatic example of a situation that is itself not uncommon, namely, that two or more different realisations can be derived from one score or set of parts. Adaptability to circumstances (liturgy, resources) seems to be the most common explanation. Here the reason is different: black symbols ender straightforward transcriptions of the vocal models, whereas the black and red symbols together constitute ornamented intabulations.

The first task a digital critical edition of these works must be able to perform is to separate the two versions. It would also allow transcriptions to be shown. Chordal transcriptions require only a small amount of knowledge to be done automatically. Despite several decades of research, satisfactory algorithms for polyphonic transcriptions have not been found yet, although there is some hope that in the future techniques for phrase extraction developed in Music Information Retrieval may help. To generate passable MIDI or audio from tablature is not too hard, for two reasons: pitch class information is exact and durations are not that critical because of the quick decay in amplitude of the lute's sound.

S.L. Weiss, Bourrée

The final case study illustrates some possibilities of displaying textcritical information. As an example we use Silvius Leopold Weiss's Bourrée (from suite ???, composed ???). It survives in seven sources; four of these were encoded as one document using TabXML (Wiering *et al.* 2005a). From this encoding we generated a series of visual presentations by means of XSLT sheets and slight adaptations of the standard ECOLM software.

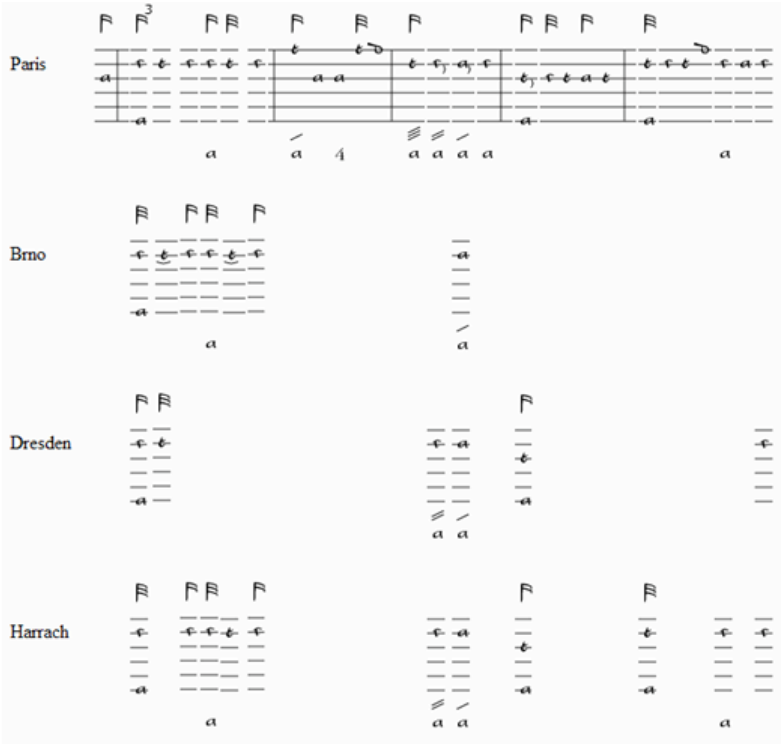


Example 5. S.L. Weiss, *Bourrée*, bars 1-11, and transcription, as in Paris source.

The simplest of these are diplomatic transcriptions of the sources, as in Example 5. From the same encoding, a critical apparatus can be generated (Figure 5). It is here shown as Tabcode (Crawford 1991), which is only slightly more cryptic than the apparatus shown in Figure 6.

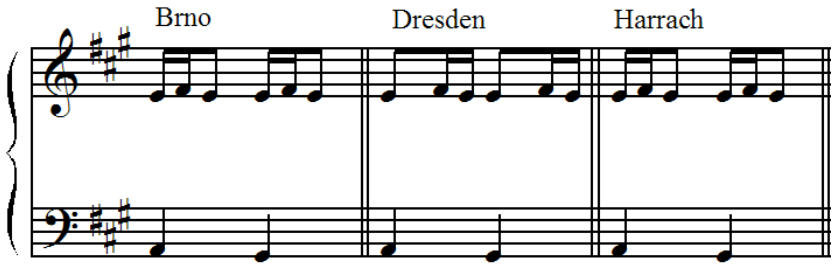
VarNr	Paris	Brno	Dresden	Harrach
1	3E	S	E	S
2	(C)		(C)	
3			S	
4		u		
5		E		E
6	E	S	E	S
7	(C)		(C)	
8	S		S	
9		u		
10		E		E
11	,	,		
12	,			
13	,	,		
14	(C)	(C)	(C)	
15	(C)	(C)	(C)	
16	(C)	(C)		
17		,		
18	(C)			
19		u		
20	(C)	(C)	(C)	

Figure 5. S.L. Weiss, *Bourrée*, first items of critical apparatus. Numbers correspond to footnote numbers in Example 5.



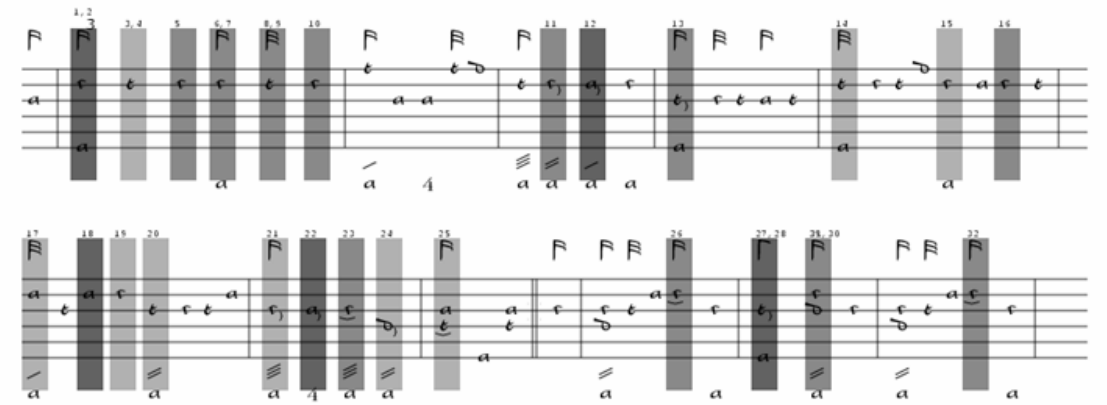
Example 6. S.L. Weiss, *Bourrée*, bars 1-5, with variants in parallel.

Example 6 gives a more intuitive view of the textcritical information, by showing one source and differences in other passages in parallel. It is easy to see now that the sources contain three different interpretations of the rhythm of the first bar (Example 7).



Example 7. S.L. Weiss, *Bourrée*, different rhythmic patterns for bar 1 in the Brno, Dresden and Harrach sources.

Taken together they suggest a performance style in which subdivisions of the beat were played *inégale*. This parallel view already allows to zoom out from the character level to the level of source relationships.



Example 8. S.L. Weiss, *Bourrée*, bars 1-11, showing variant density.

The third view (Example 8) shows the number of diverging sources for each vertical sonority in the source: the darker the background colour is, the more variants there are. This view allows to capture in one glance how unique a source is and how variants are distributed over the piece. Other than in a paper apparatus we can put variants in context and create high-level views of these.

Dimensions and views

The central idea in the model presented in this paper is that all information that relates to the edition of a composition is ordered in a multidimensional space, from which views are generated with a lower dimensionality, according to the user's preferences.

Table 1 summarises the dimensions found so far and several we assume exist in other repertoires. These are classified by SMDL domain (see section 'Critical editing in musicology'). Written sources are placed in the visual domain, performances in the gestural domain, and annotations and links in the analytical. The dimensions related to classical editorial tasks are placed in the logical domain (see section 'A multidimensional model'). Table 2 offers a similar listing of meaningful views traced so far.

Visual: written sources

- problems in source text
  - emendation
  - uncertainty
- source layers
  - scribal correction (Bach)
  - improvement (Bach)
  - performance alternative (Galilei)
  - explication (Bach)
- different sources
  - variants (Ockeghem, Weiss)
  - intertextuality (Ockeghem, Bach)

Logical: edition

- preference (Bach)
- adapt to CMN conventions
- transcription (Ockeghem, Galilei, Weiss)
- inference (Galilei, Weiss)

Gestural: performance

- ensemble composition
- interpretation
- recording

Analytical

- knowledge (Bach)
- linking (Ockeghem, Bach)

Table 1. Dimensions of the model.

Linear renditions (notation or sound)

- diplomatic transcription
- layers in source
- emended source
- edition (reading path)

Composite views

- aligned sources, editions
- apparatus
- stemma, source relationships
- musical relationships

Table 2. Sample views that can be generated from the model.

Evaluation

The multidimensional model has the following advantages:

- it represents a data-rich approach, allowing automatic extraction of information, for example by using information retrieval or statistical techniques;
- it can deal satisfactorily with different instances of a single work;
- it can incorporate performances;
- it prevents information loss caused by transcription;
- source information can be directly accessed;
- views can be adapted to specific requirements;
- a composition's musical context is made explicit by linking it to other compositions;
- editing can be done incrementally and collectively, preventing duplication of work;
- an edition stores knowledge about the composition;
- distribution is fast and cheap.

Most importantly, it aims at enhancing accepted musicological methods by overcoming certain shortcomings. Data-poorness is one important such shortcoming, difficulty in dealing with context is another one. If a significant quantity of multidimensional editions becomes available, we expect the strong distinction that now exists between generic and specific approaches to music (for example between music analysis and theory) to blur or even disappear.

We are aware that the model has a number of potential disadvantages as well, most of which are not specific to music but pertain to textual editions as well (where also some of the solutions may be found). These include:

- the complexity of the model itself, with its many dimensions and views;
- the required infrastructure, comprising data structures, software and services;
- the technical expertise editors will need to acquire ;
- the instability of online resources: they move or disappear;
- reference to an edition that itself is dynamic;
- the intellectual property of the contributing scholars and the rights of the owners of the sources;
- the status of digital publications, which is often considered less than that of paper publications with a renowned publisher.

Even though the model we propose here presents an abstract, maximum view and concrete implementations are likely to be much simpler, creating digital critical editions of music will be a complex task. It is likely to involve a team of specialists, each responsible for a certain aspect of the edition. This is a conspicuous difference with traditional editions, where an editor is typically in charge of almost the entire process. Generally, teamwork is not nearly as common in the humanities as in science, and very often editing music is part of PhD research, which is individual by nature and in practice leaves very little time for learning peripheral skills.

However, we observe that many scholars are willing to acquire complex technical skills, for example for music notation software. Such software maintains the illusion

that one works in the same way as before, only in a different, but neutral medium. As said, models like ours simplify reality with a particular aim in view. The vast majority – but not all – of those involved in music research are not used to such a scientific approach to models. Their closest counterparts in music are theories such as Schenker's, which are more in the nature of belief systems that are applied to a very wide range of tasks. Therefore these they are usually rich in escape mechanisms for solving unexpected problems. Formalised models do not allow such mechanisms and may therefore seem too simplistic or rigid to the uninitiated. This may be the most serious obstacle to the acceptance of digital, multidimensional music editions. A significant effort in educating the profession seems to be needed to remedy this. Fortunately, this burden could be shared with those promoting other areas of computational or empirical musicology, where the same problem exists.

Future work on the multidimensional model must also address its implementation. For a concrete repertoire only a restricted number of views and dimensions will be needed. This suggests a modular approach. Similarly, it must be possible to edit a work incrementally, by adding new layers of information on top of the existing ones. Much such research will be done in connection to sequels to the ECOLM project. Other areas where pilot multidimensional editions might arise are liturgical music, which must often be adaptable to the occasion; popular music, where performance is more important than notation; and folksong, where oral transmission has caused much variation. When a satisfactory incremental model for creating digital critical editions can be created, it seems only natural to integrate the efforts with other attempts at digital corpus creation for music analysis, music information retrieval and performance research.

This paper has sketched only the barest outlines of a model for digital critical editions of music. The danger of immediate technical development is that the many open issues not sufficiently debated within the broad community of historical musicology. We are therefore even more interested in critical reactions, counterproposals etc. to this paper than in the actual dissemination of this model, and hope that a debate will emerge from this similar to that in literary studies in passion and richness of ideas.

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