The search for the temporal grail?
Reflections on notation, control and digital music representations

Carola Boehm
Centre for Music Technology
University of Glasgow
carola@music.gla.ac.uk

Abstract

The central question to be addressed before starting to design any music application is how to represent music internally. My paper revisits the basics and looks systematically and thoroughly, albeit reflectively and philosophically, at music representation schemes outside the digital world: music notations in the pre-computer age. Following on from there, I ask how much of their functionality is actually supported at present. I see this as part of a search for the "holy grail in music technology", the ultimate design for music data representation (if such a thing exists). Like all other grail-hunters, this academic simply cannot stop believing in its existence. To our critics, the followers of the "not-another-standard" camp, we grail-hunters tend to maintain that the journey is part of a process – a journey towards some sort of (music-technological) enlightenment. My work has, therefore, involved looking at the methodologies used for designing systems and data structures. This paper is part of this work and looks specifically at issues around notation, control and the resulting requirements for digital representation.

Keywords : notation, data structure, representation, time

1. A Necessary Introduction about the Methodology Used in This Paper

Like many of my contemporaries, I am interested in searching for the truth – though I should say "a truth", as post-modern pluralism dictates – hence the metaphors about grail-hunting, which might be seen to be influenced by the contemporary popular book market, but which have an expressiveness that other metaphors lack. Metaphors make us understand a complex issue in more than one way; and this fact needs to be explicitly stated in our traditionally straight-and-narrow science-based approach to writing academic articles: it is academically valid, I state at this point, to be personal, philosophical, discursive and metaphorical. I am a grail-hunter for the music-technological truths behind design. I have been involved in designing systems since 1992. But back then, or more exactly in 1995, the search for and implementation of a widely usable, extensible open central music data structure was likened to providing somebody with a shotgun, potentially opening the floodgates to the misuse of music content. A shotgun? Even I thought that was a metaphor too far.

2. A Metaphor Too Far?

I did not understand the reason for such an aggressive metaphor then, but somewhere along the way of investigating music notation, digital or not, I began to understand that this fear of notational control is often the source of quite emotionally charged debate. This happened in the 1960s in Darmstadt, with extensions for modern music [1]; it also happened further back in history at the dawn of written music. There is a continuing fear of control over something so ephemeral as music.

Historically, notation, from the beginning, was associated with struggles between the notion of control and artistic /cultural freedom. Right at the beginning of our western notation, in the 8th/9th century, we find this struggle. [2] Pope Gregory the Great (590–604) had introduced a new liturgy. [3] By the 9th century this liturgy established a different tradition north and south of the Alps. Things were not as they should be in the Christian world. According to Notker's "Gesta Karoli Magni Imperatoris",

> *The Greek and Roman had always been plagued by their envy of the glory of the Franks. So that no unity and harmony could ever spread throughout the provinces, they held a meeting in order to discuss how they would be able to make the singing as different as possible.* [1]

In 789 Charlemagne had called for a unification in the the "Admonitio generalis", and founded cloister schools which taught reading, writing, Latin, psalms and psalm-melodies, the Roman liturgy and mass, the calendar, and grammar. There even seems to have been a "questionnaire" (803) which tested the knowledge of the priests in the area of liturgy. There seems to have been a "dangerous" difference in the Roman liturgy south compared to north of the alps. Whether intentionally or – more likely – through oral tradition, there is already, 50 years after the "Admonitio Generalis", evidence of at least four different methods for notating music: Daseian notation and text syllables (both found in the *Musica Enchiriadis*), neumes, and alphabetical notation. This pressure from above, this need for more control from Rome, in order to have the same liturgy north and south, can be seen as one of the driving forces behind the creation of music notations or memory aids. The church kept an interest in any method that would help this cause and even a decade later, around the year 1028, did Pope John XIX believe notation to be of such importance as to invite Guido of Arezzo to Rome, the main author behind a fast popular becoming method of notation described in his *Prologus* and *Regulae rhythm*:"[4]

So we can see why these issues might seem to be emotional ones. We are used to notation now, but common, reusable, digital representations could be seen as the new liturgy of today. With or without conflicts or not, nevertheless, the ephemerality of music continued and we, the "notationalists", continued as well. And so I ended up here, without a shotgun, but hopefully with a published paper at the end.

[1] Latin taken from [2], p. 23.

3. Music Representation Standards

Research into new ways of describing music is not new. There have been numerous different music representation standards throughout the recorded history of music addressing different needs.

So do we need another one, or, as David Halperin puts it bluntly, "Do you really need to invent a new code? The answer is: probably not." [5] And Eleanor Selfridge-Field roots for natural "incompleteness":"a 'complete' representation of all domains simultaneously… could easily produce an unintelligible mass of detail". [6]

But is that really the right question? Should we not rather be asking: Do we need models or languages for a more complete representation of music? Do we need models or representations which are flexible, modular, expandable, granular, scalable, reusable, and usable?

And here comes my sales-pitch. In order to progress in our music-computational world beyond applications which were meant for narrow application perspectives, we need models which will work across the board. In order to interchange our content information from one program to another, be able to use different representations, use different western and non-western musics in one program, we need models which work on general levels as well as deeper levels, models which can be expanded and which are scalable, models which can develop with us without becoming backward incompatible. We will need models which are "evolutionary rather than revolutionary". [7]

So, I ask, do we really need to invent yet another standard, another methodology, another paradigm? Then I would say the answer is probably: We have hardly begun!

4. The Seven Steps to Notational Heaven

Looking at traditional western music notation specifically, we can list several aspects of its own functionality: communication, control, preservation, artistic value, ownership, synchronization and study.[2] These aspects can seem trivial, and the following exploration seemingly redundant. Nevertheless, I feel that these functions need to be made meticulously explicit before we can progress to the context of digital representation.

4.1. Communication of the Musical Idea

Putting it simply, notation aids communication of the musical idea over time and space, with the musical idea being some sort of time-based structure: be it as ephemeral as a "musical meaning", or as specific as a temporal structure laid down by a notation. It might include some ambiguity, such as allowing enharmonic changes, or seemingly none at all, as specifying the frequencies. As the act of music making almost always tends to employ an intermediary, such as the performer or a machine, it needs a communication path from one to the other. On each step of this communication path several processes of abstraction and interpretation may take place. The type of message to be communicated can vary from a descriptive, action-oriented performance rule to a symbolic representation that needs interpretation.

4.2. Controlling the Performance

Usually the person or persons in the role of the creator(s), such as the composer(s), will want a certain degree of control or possibly to control the degree of control up to the point of rejecting any control. Although many modern works tend to aim at being "uncontrolled" – they include, for instance, chance or ambiguity in the notation – our society accepts the fact of art-based "intellectual property". With the persistence of the belief in ownership of intellectual property, the need to be certain that one's own creative product is creative, unique AND one's own still remains as one of the more important aspects within music-making activities. This implies maintaining a control over what the receiver or listener gets: it has to be ensured that listeners/receivers get what the creator intends them to get, even if this includes ambiguity as a characteristic of the piece.

4.3. Preservation

A third functionality is the preservation of a fleeting form such as performed music. Until the time when other means of mechanical, electronic or digital recording of information were accessible, notation was the only mechanism available for making music persistent over time and space. Although other means for persistency have now been made available – recording, for example – these are still very often considered to be interpretations, rather than the work or opus itself.

4.4. Symbolic Meaning through Visual Impact

Notation has always had a more or less "graphical" artistic value associated with it; our common western music notation has established a form which is not only easily decipherable but also aesthetically pleasing to the eye. Our treble clef sign, for instance, has developed to its modern form not only because of pure functional factors but also because of an aesthetically pleasing look and pen flow. The notated work in itself has often had, in our western history, this additional meaning of being a work of graphical artistic value. It was often not just a score but, in a way similar to a painting, could convey with music and art a deeper meaning, in a graphical manner as well as a musical one.

An example of this can be seen in a four-part canon without text by Bartolome Ramos de Pareja (*c*.1440–*c*.1491). [8] As is relatively often the case with canons, this four-part canon has been presented in graphical and iconic form. The beautiful miniature (24 x 17 cm) depicts winds in humanoid form blowing from the four directions into the circle of notated music, symbolizing the way this has to be sung, although there is no text. [9] Another example can be found in Kyrie I from Missa Salve diva parens by Jakob Obrecht (1450–1505), [10] which was painted for the wedding of Maximilian I and Bianca Maria Sforza in November 1493.

This tradition carries on into modern times, sometimes with the effect of the actual performance being only secondary. "Music" in the twentieth century often became more similar to a work of visual art than performing art. Music has often tried to express itself through other means than a mere set of instructions for a performance; it often wants to con-

[2] Reinterpreted here, the seven functions of notation were mentioned in similar form in P. Donachy, "Other Routes of Escape from the Cage of Our Own Traditional Symbolisms" (unpublished MA thesis, Glasgow, 1999).

vey meaning, and graphical notation and visual art can be aspects of this.

4.5. Providing a Tool for Composition and Study

Another function of music notation has always been the ability to aid processes of study or processes of composition. Our common western music notation developed in the direction of enabling us to see harmonic (vertical) and melodic (horizontal) structures very easily. Not only on this high level, but also on a much more detailed level, graphical elements of our common music notation provide non-explicit information about the structure, the interpretation, the meaning or the performance of a work.

It becomes clear just what a unique achievement the development of the common western music notation is when one acknowledges that the full complexity of a solely time-based domain has been abstracted into a complex, but easily understandable, two-dimensional representation of itself. As it seems that the human mind has more difficulty in grasping structures in the temporal plane, the transfer to a two-dimensional plane on paper makes it possible to find structures in a two-dimensional domain which represent clearly, but in an abstracted form, structures in a time-based domain. As the score has played such a great role in the process of composition and performance for many centuries, it has come to mean "the music". This concept and value has only been brought into question in the twentieth century due to influences from jazz and improvisation, the popularization of non-western music traditions, and other popular music cultures, which bypass scores for performance and composition.

Nevertheless, the score was, for a long time, also the tool to compose with, and it would have been quite interesting to undertake some psychological tests of composers throughout the ages, and investigate if composers using a score as a tool for composition either hear the music in their mind and then put it to paper or if they see structures on the paper and verify it with reading the music in their mind or even do both simultaneously. My guess would be that we would see the whole variety in-between these two possibilities, demonstrating that the notion of composing on a "non-time-based plane" purely with two-dimensional structures symbolizing time-based entities is one of the major achievements of our common western music notation: graphical elements allow composers to easily construct structures out of larger elements of 'music' and are thus "tools for composition".

And if one thinks the word "tool" is too far-fetched in this context, one only needs to go back to the time, in the sixteenth to the seventeenth century, when the vertical aligning of different staffs became common, vertical composition techniques became more common than linear contrapuntal methods, and composers regarded the "composing in (staff) systems" as a tool to achieve this vertical-ness of the music. [11] Auctor Lampadius, for instance, presented a supporting tool in his book *Compendium Musices* [12] in 1537, the "Tabula compositoria", a device to help composers to easily design understandable scores. A "score", with systems and aligned staffs, was not yet used nor seen as the "Werk" itself (the opus) but rather was seen as a means, or a tool for supporting compositional processes.[3] [13, 14, 15, 16] Thus we have an early example of a type of score being seen as a tool to help vertically align staff and systems to help compose in a very specific way.

4.6. Ownership

The last couple of centuries of music publishing have made the score the main item of what the German term "Werk" and the Latin term "Opus" tend to express. Especially with the rise of music publishing, the industry needed something physical to attach ownership to, and it found it in the score. Not only was it something that one could hold in one's hands, but one could also duplicate it and sell it on. The score was the "Werk": it was the proof that it had been created by a specific composer.

Only now, well into the age of mechanical or electronic (and digital) recording of performances, is it possible to associate ownership of a piece of work with a medium other than the score.[4]

4.7. The Art of Playing Together

A last, and possibly the most trivial, functionality of any music description is the goal of being able to represent a method of synchronizing time-based structures when performing the piece. Notation allows us to "read" two-dimensionally how we are to play in a synchronized temporal mode, rather than to remember. The old methods of remembering have been generally de-emphasized in our modern world for the sake of the advantage of "reading" and knowing where to read.

5. Functional Comparison with Applications using Digital Music Representations

If these seven main functionalities are valid for music notation, than it is not too much to demand that music applications which have notations as a means or a goal should support these functionalities. The seven functionalities could be said to represent the users' needs, tested throughout the last 300 years of our western music history, and verified by the general acceptance of our common music notation. The interesting aspect is that only part of this list is realized through software available today, certain functions are only supported on a very basic level, and some have only been added as features in the last few years. Seldom has the attempt been made to support all or a more comprehensive list of these functionalities in currently available notation or music systems. Even though we may have to acknowledge the increasing diversity of applications and their digital music representations which tend to lack any common purpose,[5]

---

[3] See several authors who have mentioned the "Tabula Compositoria" and interpreted it as meaning different things, from early forms of composing automations to rules for composition. Amongst these are:Michael Harenberg [12], Jessie Ann Owens & Martin Ruhnke [13], E. Lowinsky [14] and S. Hermelink [15].

[4] This is addressed in US Public Law 92-140, Feb. 15, 1972.

[5] The apparent dichotomy between a "relatively well-understood phenomenon" such as traditional notation, perceived as a unity and a "wide range of representations and applications that lack any common purpose" was noted by an anonymous reviewer in 2006.

what if we take the above functionalities of our common western music notation as the hypothetical result of a requirements study and apply them to music applications. How do our present applications and standards fare in this comparison?

5.1. Communication Support

The notion of integrating more communication support between individuals in the process of making, creating or investigating music has only been integrated in research projects. The support of some form of web-based dissemination and web-based publishing, if one puts this notion under the heading of communication, has only been added in the last few years. The companies responsible for the two major commercial notation packages, Finale and Sibelius, have both created web-based plug-ins which read their proprietary Finale and Sibelius files, and are able to display and play music on a page basis with automatic page-turning, transposition, and printing features. Another example could be seen in the research work by Holger Hoos and his group, who have developed the GUIDO music notation format and a server–client rendering system which makes it easy to include music notation in web pages. [17] Some XML developments in music description could be seen in this light as well.

But none of the commercial packages cater in depth for collaboration between individuals making or creating music, which would need to include synchronization management support as described below.

5.2. Synchronization Support

Some research projects have investigated aspects of synchronization to support collaborative activities. The system by Ossenbruggen and Eliëns [18], which is based on client–server architecture, uses an SMDL-like language with MIDI and enables collaborative performances. Another important milestone was the MOODS (WEDELMUSIK) system (music object oriented distributed system) [19] which was also based on a client–server architecture and allowed the synchronized and simultaneous representation and annotation of music scores for performance, thus making it possible to replace scores for large orchestras. On the standards side, the development of an extension to MIDI, "Distributed Midi", by Phil Kerr at our Centre for Music Technology here at the University of Glasgow [20], enabled it to be streamed through an Ethernet port.

5.3. Performance Control Features

The notion of controlling the performance is present in almost all composition systems, such as Csound and Max and their dialects, PD, KYMA, Mode and SIREN (and one could even add proprietary and closed systems such as Cubase and Protools to this list).

But most of the composition systems do not cater adequately for presenting music professionally in a score-based fashion. Although many composers who work intensively with these packages would probably insist that they do not need score-based presentation, it still has to be said that the majority of music is still composed with a view to score-based presentation, or at least is transferred after recording into some form of score-based notation.

This holds true in classical as well as popular music, and the distribution of the latter happens not only through CD and MP3-download sales, but also through the sales of single songs as sheet music. Furthermore, when doing a rough survey of composers and artists and their use of computer-based tools for creative purposes, an EU project found [21] in 2001 that only a very small percentage use computer-based tools and then only part of the time. Although there may be different reasons for this, it can be assumed that one explanation lies in the lack of features catering for the needs of these artists, of which the production of score representations might be one. Many artists, even ones who use computers as compositional tools, still feel the need to be able to control the performance, and many feel the score to be the major piece of evidence for their intellectual creative work.

5.4. Digital Persistency

One might naively assume that in our digital world persistence is made easy through the fact that digital data is not as easily damaged as analogue data. Far from it – several European funded working groups have found that one of the major reasons for the lack of uptake of computer tools for creative processes is the lack of permanence. "Digital Art needs to be resistant in time and space for at least 20 years in order to be considered for use by the critical mass of artists." [22]

So persistence seems to emerge as one of the biggest problems for the acceptance of digital tools in creative use contexts. New versions of software are not always 100% compatible with old versions and this provides immense and constant data migration problems, which artists do not want to be burdened with.

Other software only lasts for a few years and its continuing support through the operating system may not be guaranteed, especially when upgrading operating systems themselves. Licenses also make life difficult, as they often need to be maintained, and a change of system can lead to a requirement for a lengthy and cumbersome application for a new license without the purchase of another version of the software. All in all, digital technology often does not seem to convey enough confidence in using these tools for actual works of art (as opposed to the process of creating art) which artists want to be readily accessible by themselves over large lengths of time and anywhere.

5.5. Arbitrary and Artistic Graphic Support

The feature of adding more visual artistic support, above the usual support needed for a graphic music score, has been exploited to quite an extent, but often in one-off, specifically visual artistic applications for specific performances. This is one area of growth in our interdisciplinary world in which areas and cultures are merging. There are composition tools which have added support of graphic output (MAX, PD, GEM for PD), or even systems which began by being mainly graphic and added additional sound tools to their output (VRML applications, X3L, Cave applications, gaming environments). Animation, games, and mixed media art provide creative solutions not only for sound but also for display. Nevertheless, most of the systems do not support our common music notation, and most of the ones which do support it do not support more graphical freedom. Even our classical

modern notation packages often still have difficulty with more unusual notation symbols.

5.6. Supportive Tools for Composition and Study

Not many applications provide a tool for composition and study, but there are a few. For composition, for instance, the Composer's Desktop Project provides an expandable set of tools based on Csound. Most sequencing software provides compositional support, even if mostly through proprietary and closed standards and toolsets, and has been criticized for training users in a "template way of thinking", i.e. the mass production of creative output with minimal effort.

In education, there are just a very few applications and these are primarily for a specific purpose. Most of them were created in research projects for a specialized academic community. For the study and analysis of music there is, for example, HUMDRUM. Powerful notation packages could be used for basic analysis as well, but to a much lesser extent than HUMDRUM. Specific projects have produced very specific solutions, such as Schenkerian analysis, or similarity matches with one specific algorithm being used. Most of the commercial packages that come under this heading tend to be for very specific purposes and, more importantly, their underlying music data structure or music description is hidden and seldom known. This might be considered not only academically unsound, as the use of certain "hidden" underlying structures in analytical studies of the music may influence the result, but also unwise in terms of design and expansion of functionality as well as possibly ethically unsound in terms of open source issues.

So even though there might be music descriptions out there which support this category of functionality, the majority of them are either on the one hand inaccessible, unexpandable and/or proprietary, or on the other hand specific, targeted and for a narrow usage. The case has been made that just as composers using computer-based tools in Britain got together and gathered a whole toolset (the Csound-based Composer's Desktop Project), there is the need for a toolset collection relevant to musicology, based on an open, expandable and powerful music description standard. Some of the newest promising developments in this area, albeit with heavier emphasis on audio rather than structured music, can be seen in the CLAM C++ Library for audio and music (UPF)[6] and the M2K (ISMIR) music information retrieval rapid prototyping system for audio and music.[7]

5.7. Supporting Ownership

The notation of the musical idea enables ownership of the idea. This last functionality – ownership – is quite a controversial one in the age of "uncountable technical reproduction" [23], "open source", and control by the few large publishers and record labels. With the growing number of stakeholders in copyrighted material, it is beginning to be argued that the current legal issues surrounding copyright and IPR (Intellectual Property Rights), which initially were developed to protect the creator, are leading to a situation which is a cultural and creative dead-end. Contrary to the original purpose, creative individuals, and those dealing intellectually with the content, have not had their vested interests secured. Rather, they have been restricted in their possibilities of using and manipulating content for creative or analytical purposes, and have left the distributors winning and gaining the largest part of the income with the least amount of effort. The interests of these two groups stand in direct conflict. This struggle over who owns what and what can be owned has emerged just at the time when technology would actually allow us to bypass high-effort distribution frameworks, on which distributors base their high share of profits.

Thus distributors – such as labels, big IT companies, and publishers – normally support the development of closed and proprietary standards. These do not allow the transparent viewing of what is actually being written into the description of the music, nor of how the music is stored and described. In addition to this, additional hidden information is added for an even greater degree of control, using techniques such as digital watermarking or digital fingerprinting. All this obviously fits in very well under the aspect of control, as it results in the controlled and monitored use of the creative work. This only works because there is such a thing as ownership of a specific use of a certain piece of creative work.

To repeat and emphasize this issue: these techniques are only used in a minor way to identify and provide control to the owner of the creative idea. Today's third-party distributors have the largest vested interest in making money out of the distribution of the idea, not in the ownership of the idea itself. Thus hidden information in digital data is used less to denote the ownership of the creative musical idea, and more for ownership and control over a certain way of using or distributing this musical creative idea.

It simply has to be said that this is one functionality which our musically active developers' community should consider supporting only with regard to openness and transparency; they should not cater to the industries' demand for control of usage and distribution.

6. Summary

When I talked about evolutionary models, rather the revolutionary models, I mentioned the concepts of representational completeness, flexibility, expandability, granularity, scalability, reusability, compatibility and usability. It has to be recognized that there are many developments which go a long way towards achieving these goals. To name but a few there is the whole application group around MusicXML which has sparked the imagination of many developers. Finale and Sibelius Plugins allow MusicXML to be im- and exported with Recordar's Dolet 3 [24]. It has allowed the interchange of notation files between different packages, such as Finale, Sibelius, Lilypond and Rosegarden, albeit some of those only in one direction. It has already achieved a wider popularity than, what back in the nineties, NIFF, the notation interchange file format, tried to achieve [25]. Many

6 This library is being developed by the UPF Music Technology Group to provide basic toolboxes and infrastructure for its projects, but also to increase synergies and algorithm-sharing among different groups. It tries to provide a proper algorithm encapsulation, communication and parameterization. (Announced on DMRN email list, 04/03/2005.)

7 Project headed by J. Stephen Downie. More information available at http://music-ir.org/evaluation/m2k, last accessed 03/04/2005.

others are presently worked on and in the field of looking for design and evaluation principles and methodologies some publications to mention are Huron's *Design principles in computer-based music representation (1992)* [26], Byrd/Isaacson's *A Music Representation Requirement Specification for Academia (2003)* [27], Selfridge-Field's, *Beyond Midi (1997)* [6], Dannenberg's *Music Representation Issues (1993)* [28], Wiggin's *A Framework for the Evaluation of Music Representation Systems (1993)* [29] and Hewlett/Selfridge-Field's, *The Virtual Score (2001)* [30].

When Selfridge-Field discusses issues in musical representations, she mentions the limits that, according to her, are inherent in the problem of encoding music:

> *In large measure, all systems for representing music are selective in some way, just as all (geographical) maps are selective in the information they provide. The privileging of one domain may be as essential as it is practical: a "complete" representation of all domains simultaneously, requiring the same kind of superimposition as we can imagine in these maps, could easily produce an unintelligible mass of detail.*[5]

But if we go beyond thinking in codes, then it will be possible to come much closer, maybe not to a complete representation, but at least to one which can be expanded and extended and be so flexible as to one day have the chance of seeming to be representationally complete and including as many functionalities as our common music representation has catered for over the last 300 years, including communication, synchronization, performance control features, digital persistency, arbitrary and artistic graphics, tools for composition and study, and ownership.

---

[1] E. Karkoschka, *Notation in New Music: A Critical Guide to Interpretation and Realisation*, translated from the German by R. Koenig (London: Universal Edition)

[2] H. Möller, "Die Schriftlichkeit der Musik und ihre Folgen", in C. Dahlhaus, L. Finscher, G. Schubert, M. Zimmermann and U. Mosch (eds), *Funkkolleg Musik Geschichte. Europaeische Musik vom 12–20. Jahrhundert, Studienbegleitbrief 2*, Der Ursprung des Musikwerks (Mainz: Schott, 1987), p. 33

[3] Einhard (Fulda), "Vita Karoli Magni", in [2].

[4] C. V. Palisca, "Guido of Arezzo", *Grove Music Online* ed. L. Macy, http://www.grovemusic.com [16/06/2006]

[5] D. Halperin, "Afterword: Guidelines for New Codes", in [5], p. 573.

[6] E. Selfridge-Field, *Beyond Midi* (Cambridge, Massachusetts: MIT Press, 1997), p. 568

[7] S. T. Pope, "Object-Oriented Music Representation", *Organised Sound 1*, no.1 (1996), pp.55–68, at p. 58

[8] Florenz, Biblioteca Nazionale Centrale, Ms. Banco Rari 229 (Magl.XIX, 59), 24 x 17 cm, fol. C.III.b

[9] H. Besseler and P. Gülke, "Schriftbild der mehrstimmigen Musik", in *Musikgeschichte in Bildern. Band III*, Lieferung 5, p.124

[10] Wien, Österreichische Nationalbibliothek, Ms.S.M.15.495, 55x38cm, fol.1v–2r

[11] C. Boehm, "Automated Music. Interdisciplinary Aspects of a Developmental History: Middle Ages and Rennaissance", in *Proceedings of the International Computer Conference* (Hong Kong: ICMA, 1996)

[12] Auctor Lampadius, Compendium Musices, Bern 1537 (Berne, 1537, 5/1554)

[13] M. Harenberg, *Neue Musik durch neue Technik? Musikcomputer als qualitative Herausforderung für ein neues Denken in der Musik* (Kassel, 1989), p. 25

[14] J. A .Owens and M. Ruhnke, "Auctor Lampadius", in S. Sadie (ed.), *The New Grove Dictionary of Music and Musicians* (London: Macmillan, 2001)

[15] E. Lowinsky, "On the Use of Scores by Sixteenth-Century Musicians", *JAMS*, i/1 (1948), pp. 17–23; repr. in *Music in the Culture of the Renaissance and Other Essays* (Chicago: 1989), pp. 797–802

[16] S. Hermelink, "Die Tabula compositoria: Beitrage zu einer Begriffstimmung", in *Festschrift Heinrich Besseler*, ed. E. Klemm (Leipzig: 1961), pp .221–230

[17] H. Hoos, K. Hamel, K. Renz and J. Kilian, "The GUIDO Music Notation Format – A Novel Approach for Adequately Representing Score-Level Music", in *International Computer Music Conference Proceedings* (ICMA, 1998), pp. 451–454

[18] J. van Ossenbruggen and A.Eliëns, "Music in Time-Based Hypermedia", Vrije Universiteit, Amsterdam, 1994. Av.: http://www.cs.vu.nl/~jrvosse/Papers/echt94/html/index.html [01/07/1998]

[19] MOODS – TETRApc HPCN ESPRIT Project n.25968, Av.: http://www.dsi.unifi.it/~moods/moods/mp_over.htm [23/03/2005]

[20] P. Kerr, *Dmidi*, IEEE P1639

[21] "Report on Workshop on Technology Platforms for Cultural and Artistic Creative Expression", 21–22 May 2001, Darmstadt, Germany. Av.: http://www.cordis.lu/ISTweb/KA4/Vision/Darmstadtconclusions/ [10/12/2001]

[22] CIRCUS 2001, "New Synergies in Digital Creativity", in *Proceedings of the Conference for Content Integrated Research in Creative User Systems* (Glasgow: University of Glasgow, 2001)

[23] W. Benjamin, *Das Kunstwerk im Zeitalter seiner technischen Reproduzierbarkeit* (Edition Suhrkamp, Nr.28, 1963)

[24] Recordare Internet music publishing and software, http://www.musicxml.org/ [15/06/2006].

[25] Cindy Grande et alii, "Specification for the Notation Interchange File Format (1995)," http://esi24.ESI.UMontreal.CA:80/~belkina/N/NIFF6a3.txt, [05/06/2000].

[26] D. Huron, "Design principles in computer-based music representation", in: Alan Marsden & Anthony Pople (editors), *Computer Representations and Models in Music*, London: Academic Press, (1992) pp. 5-39

[27] Donald Byrd and Eric Isaacson, "A Music Representation Requirement Specification for Academia", in *Computer Music Journal 27(4)* (2003);

[28] R. Dannenberg, "Music Representation Issues, Techniques, and Systems." In *Computer Music Journal 17(3)* (1993), pp.20–30.

[29] G. Wiggins, et al. "A Framework for the Evaluation of Music Representation Systems", in *Computer Music Journal* 17(3) (1993), pp.31–42.

[30] W. Hewlett and E. Selfridge-Field, eds. "The Virtual Score: Representation, Retrieval, Restoration", in: *Computing in Musicology 12*, (2001).