Music Score Watermarking

P. Nesi
University of Florence, Italy

M. Spinu
EXITECH S.r.L., Certaldo, Italy

INTRODUCTION

Music publishers, authors and/or distributors have high quantity of music scores in their archives. In classical music, the original music piece is normally kept in paper format, since its production goes back to many years ago. At present, only new light and popular music pieces are in symbolic notation formats. Light and popular music have a limited lifetime when compared with classical music pieces. The duration of the copyrights for that kind of music is about 60-80 years. Content owners are very cautious to transform their classical music pieces in digital format for e-commerce purposes, because they consider it as a highly risky process which could ultimately lose their copyright ownership. The situation is different when it comes to light and popular music, being market life shorter. According to content owners' opinion, e-commerce for music distribution cannot be accepted, unless adequate protection mechanisms are provided, as highlighted in WEDELMUSIC (www.wedelmusic.org) and MUSICNETWORK (www.interactivemusicnetwork.org). They accept to have their music protected only if it is possible to control while at the same time the users exploit content functionalities according to the established permissions and prices. To cope with these problems, mechanisms for protecting digital musical objects are used (see Table 1).

In this article, only problems and solutions for protecting and watermarking music scores are discussed.

Most music scores are still kept in paper format at publisher's archives. A first step to transform them into digital documents can be transforming them into images with a scanner. Another possible solution can be found in transforming them manually into symbolic music with a music editor. Obviously, this latter solution is very expensive, since the music has to be totally retyped. The use of very efficient Optical Music Recognition (OMR) software, similar to the Optical Character Recognition (OCR), seems to be quite unlikely in the next future. Currently, their recognition rate is close only to 90%, which makes this approach not too much reasonable when compared with retyping (www.interactivemusicnetwork.org, see assessment on the Working Group of Music Imaging).

Music images or symbolic music are obtained after music sheet digitalization. In the event of images, no further music manipulation is possible at the level of symbols. On the other hand, images can be easily viewed in any operating systems and with plenty of applications. The symbolic music gives several advantages in the score maintenance and manipulation; it allows the user to perform changes on the music, such as to justify it, change the page settings, add ornaments, accents, expressions, view single parts or the whole score, and so forth. The drawback consists in all these possible operations being performed only if the music editor is available: professional music sheets are produced by expensive and professional music editors.

It is well known that music sheets are distributed in paper format among musicians. Therefore, it seems that such digitizing process is useless. Practically speaking, Internet music sheet distribution, meaning from publishers to consumers, can only be achieved using digital formats. Distribution among users, as it occurs now with photocopies, could be made even via digital music sheets, as Napster did with audio files. Please note that on P2P (peer to peer) application there is also a quite significant

Table 1. Mechanisms for protecting digital musical objects

• encryption techniques to support any transferring of music objects;
• watermarking audio files in different formats;
• watermarking images of music score sheets;
• watermarking music sheets while they are printed from symbolic notation files.
• definition of digital rights management policies.

distribution of music scores (www.interactivemusicnetwork.org, read report on Music Distribution Models of the Working Group on Music distribution).

Whenever using digital formats, music could be converted again into paper (today musicians play music only from paper sheets).

BACKGROUND

The most relevant features for algorithms of score watermarking can be summed up into three categories (Monsignori, Nesi, & Spinu, 2003):

- *Content Requirements:*
  The embedded data may contain a simple identification code, which allows to recover the publisher and the distribution IDs simply by consulting a Web service. To this end, hiding about 100 bits is typically enough. The code can be encrypted, compressed and may include control and redundant bits to increase robustness.
- *Visual Requirements:*
  The watermark inserted in the printed music sheet has to be invisible for musicians or at least it should not bother musicians during their execution.
  The watermark has to be included in the music printed by the final user in any format if the music is available in symbolic format. Therefore, the watermark reading has not to depend on the availability of the original reference image of the music sheet.
- *Resistance Requirements:*
  The cost to remove watermark must be extremely expensive when compared to any regular purchase of the same music sheet.
  The watermark must resist against music sheet manipulation until the music printed becomes unreadable. Typically, five levels of photocopy are enough to make music unreadable or of a very bad quality.
  The watermark has to be readable when processing each single page or smaller part.

In addition, there are other parameters to be taken into account in order to analyze the technique capability.

- The amount of embedded information has a direct influence on watermark robustness. Typically, the hidden code is repeated several times in the same page; therefore, the bigger is the code, the lower is the number of times such code can be repeated, which means a decrease in the general robustness.
- Embedding strength " There is a trade-off between watermark embedding robustness and quality. Increased robustness requires a massive embedding of hidden bits. This increases music score degradation and watermark visibility.

Please note that watermarking images of scores or watermarking symbolic music lead to the same result: a watermarked music sheet. The watermarked music (symbolic or image) should be kept in some unchangeable digital file formats (like PDF) or in some formats difficult to change (PostScript), image format. The implementations of the algorithms for music watermarking in such two events are completely different (Busch, Nesi, Schmucker, & Spinu, 2002). In the first event, the watermarking is performed while the music score is printed by manipulating graphic primitives such as lines, music fonts, and so forth, and the process may generate a PostScript file or may send the information directly to the printer. In the latter case, the watermarking is performed by manipulating the B/W images.

In order to read the watermarked hidden code, the music sheet has to be scanned and the resulted image has to be elaborated with the watermark reader, to reconstruct the embedded code. The main advantages of distributing symbolic music sheets, instead of images are:

- Lower number of bytes for coding music, easier distribution, lower costs of download, and so forth;
- Higher quality of the printed music sheets, depending on the printer of the final user;
- Possibility of manipulating music notation for transposing, adding annotation, rearranging, and so forth; and
- Possibility of performing a direct music execution from symbolic format to produce MIDI or extended MIDI formats.

All of these features make the use of symbolic music more interesting for music distribution, and therefore its watermarking is very important for music protection.

APPROACHES

According to the user requirements, the printed music sheets must be produced at high resolution and quality. In appreciated music sheets, there is no noise, meaning that the information is in black and white, and therefore no space is left to hide information inside noise or in any kind of noise added-image. This means that the hidden code can be included only under the shape or in the position of music notation symbols. According to such purpose, some common elements of music sheets can be considered: staff lines, stems, note head, bar lines, and so forth.