An IEEE 1599 Framework to Play Music Intuitively
The Metapiano Case Study

Luca Andrea Ludovico[1] and Mario Malcangi[2]
[1]*Laboratorio di Informatica Musicale (LIM), Milan, Italy*
[2]*Digital Signal Processing & Real-Time Systems (DSPRTS), Dipartimento di Informatica, Università degli Studi di Milano, Via Comelico 39, Milan, Italy*

Keywords: Education, IEEE 1599, Music Meta-instruments.

Abstract: This work aims at proposing an innovative way to approach music education. The idea is coupling the power of IEEE 1599, an XML-based international standard for music description, to the concept of music meta-instruments, namely new interfaces conceived for a simplified interaction with music contents. The proposed framework will provide a tool for music practice, powered by the multiple and heterogeneous contents contained in an IEEE 1599 document. A case study based on Jean Haury's metapiano will be presented.

1 INTRODUCTION

Music education is evolving in several directions using electronic, information, and communication as enabling technologies to make the teaching process more effective and to enhance the human ability to learn. Computer-assisted musical learning has several approaches. Musical games, a subset of computer games, are finalized to enable kids to interact with music intuitively, stimulating different types of intelligence, such as the instinctive, intuitive, and sensory-motor one (Wechsler, 1975). The application of computer games to music education has been discussed in a number of scientific works - see e.g. (Denis and Jouvelot, 2005) - and exploited in many experiments - see e.g. (Kim et al., 2008).

In this paper we want to introduce a new paradigm for music education, based on the concept of meta-instrument. A *musical meta-instrument* (Miranda and Wanderley, 2006; Malcangi and Castellotti, 2013) can be either a virtualization of an existing instrument or a brand new one; in any case, it is conceived to move the sound generation and texture capabilities into the instrument itself, and to leave sequencing and timing under the performer's control. In this sense, it aims at being closer to the natural and intuitive ability of the performer, in order to enable him/her to play music without a specific technical skill. In our opinion this new learning paradigm is extremely innovative since it could remove any starting barrier between the person and the instrument.

The behaviour of a meta-instrument somehow resembles an orchestra conducted by a director. In fact such a tool requires a score in input but it has no knowledge about timing and interpretation in itself: it acts like an orchestra player waiting for conductor's instructions. The gestures required to produce sounds are demanded to a human player, who - freed by a number of technical constraints - should be able to perform music in a more straightforward way.

The activity of playing a meta-instrument, when instanced in an appropriate context, can become a kind of music game. It is worth citing the case study of the popular console video game *Guitar Hero* (Miller, 2009), which documents the changing nature of amateur musicianship in an increasingly technological world. The framework we will propose in the following is not oriented to pure entertainment, rather to edutainment. It aims at constituting an entry point to music learning, also for handicapped students who have physical, mental or health impairments.

In our approach, two key paradigms of music - namely the writing-oriented and the performance-oriented paradigms - are mixed for educational purposes. This experiment has already been successfully conducted in other contexts, for instance in electroacoustic music composition, as reported in (Desainte-Catherine et al., 2013).

In order to transform the concept of musical meta-instrument into a real tool to play intuitively, we propose a framework that embeds meta-instrument notation in the IEEE 1599 format. The latter is an XML-

Andrea Ludovico L. and Malcangi M..
An IEEE 1599 Framework to Play Music Intuitively - The Metapiano Case Study.
DOI: 10.5220/0004937904090414
In *Proceedings of the 6th International Conference on Computer Supported Education* (CSEDU-2014), pages 409-414
ISBN: 978-989-758-020-8

based international standard for the representation of music in all its aspects. Section 2 will present the key concept of IEEE 1599, whereas Section 3 will provide details on the proposed solution.

Finally, Section 4 will introduce a clarifying example based on the experience of Jean Haury's metapiano. This already existing tool has been adopted in our case study to test the effectiveness of a "meta-instrumental" approach to music education.

2 AN OVERVIEW OF THE IEEE 1599 FORMAT

IEEE 1599 is a standard internationally recognized by the IEEE, sponsored by the Computer Society Standards Activity Board and designed by the Technical Committee on Computer Generated Music. IEEE 1599 adopts XML (eXtensible Markup Language) in order to describe a music piece in all its aspects (Baggi and Haus, 2009).

The innovative contribution of the format is providing a comprehensive description of music and music-related materials within a unique framework. The symbolic score - intended here as a sequence of music symbols - is only one of the many descriptions that can be provided for a piece. For instance, all the graphical and audio instances (scores and performances) available for a given music composition are further descriptions, as well as text elements (e.g. catalogue metadata, lyrics, etc.), still images (e.g. photos, playbills, etc.), and moving images (e.g. video clips, movies with a soundtrack, etc.).

Comprehensiveness in music description is realized in IEEE 1599 through a multi-layer environment. The XML format provides a set of rules to create strongly structured documents. IEEE 1599 implements this characteristic by arranging music and music-related contents within six layers:

- *General* - music-related metadata, i.e. catalogue information about the piece;
- *Logic* - the logical description of score in terms of symbols;
- *Structural* - identification of music objects and their mutual relationships;
- *Notational* - graphical representations of the score;
- *Performance* - computer-based descriptions and executions of music according to performance languages, such as MIDI or MPEG4;
- *Audio* - digital or digitized recordings of the piece.

Music events are univocally identified in the encoding, so that they can be described in different layers (e.g. the graphical aspect of a chord and its audio performance), and multiple times within a single layer (e.g. many different music performances of the same event). Consequently, in the multi-layer environment provided by IEEE 1599, one recognizes two synchronization modes:

1. *Inter-layer synchronization*, which takes place among contents described in different layers. Different layers store - by definition - heterogeneous information, to allow the enjoyment of heterogeneous music contents simultaneously, in a synchronized way. Applications involving multimedia and multi-modal fruition, such as score following, karaoke, didactic products, and multimedia presentations, can be realized thanks to this kind of synchronization;
2. *Intra-layer synchronization*, which takes place among the contents of a single layer. Each layer contains - by definition - homogeneous information. Thanks to this feature, one can jump from an instance to another instance of the same type in real time, without losing synchronization.

Coupling the aforementioned kinds of synchronization, it is possible to design and implement advanced frameworks for music. For further details about the format, please refer either to the official IEEE documentation or to a recent book covering many specific aspects of the standard (Baggi and Haus, 2013).

In this context, the most relevant aspect is the possibility to integrate and synchronize within an IEEE 1599 document many heterogeneous kinds of description, including any form of meta-instrument notation. This matter will be discussed in depth in the next section.

3 THE PROPOSED FRAMEWORK

In our approach, two activities can be clearly distinguished: *music encoding* and *music performance*. Usually they are asynchronous, since the former can be completed before the performance, and often this is even required by a number of technical issues. In fact, for our goals music encoding implies the production of a "rich" IEEE 1599 document, namely a single XML file containing both the spine and the meta-instrument notation, mutually linked. Encoding music in a proper way during a live performance is a

```
1 [] 1 63 [< 4 70 [< 3 75 [< 2 79
2 [>  4 70 [> 3 75 [> 2 79 [] 1 75
3 [] 1 74 [< 4 67 [< 3 70 [< 2 79
4 [] 1 70
5 [] 1 72
...
```

Figure 1: A short example of plain-text notation for J. Haury's metapiano. The score contains voice, pitch and velocity encoding, together with basic information on articulations.

hard task, even if theoretically feasible (Baldan et al., 2009).

Needless to say, an IEEE 1599 document can contain much more, as explained in Section 2. For instance, it could host a number of pre-recorded audio tracks referring to other performances of the piece, or conceived as a background for the current performance.[1] Similarly, the *Notational* layer could host evocative graphics together with a traditional score version in common Western notation.

A number of IEEE 1599 applications oriented to music education has been treated in (Baratè et al., 2009) and (Baratè and Ludovico, 2012). In this context, the novelty is the presence of meta-instrument notation. Usually it contains basic symbolic information (i.e. notes, rests, a few articulation signs, etc.), namely the input required by the meta-instrument parser. A simple example is the notation for the metapiano by Jean Haury, illustrated in Figure 1. It is worth underlining that the information contained in a meta-instrument score is potentially redundant with the contents of the *Logic* layer, and actually the knowledge of encoding rules makes an automatic conversion possible between formats.

Moreover, software tools and plug-ins have been developed to compile the *Logic* layer starting from commonly adopted formats (e.g. MusicXML and MIDI) as well as score editing software (e.g. MuseScore, MakeMusic Finale® and Sibelius®). Similarly, computer applications could be implemented for *ad hoc* meta-instrument scores, too.

IEEE 1599 provides richness in music description, including multiple audio, video and score digital objects. Since the format supports any representation of score symbols, also new notation for music meta-instruments can be embedded and synchronized with all the other contents.

[1]Please note that in this case timing information would be implicitly provided to the human player. Such a result could be either desirable, e.g. to teach students how to go in time with the music, or unwanted, e.g. to make children express themselves during Music Therapy sessions.

After producing the IEEE 1599 document, the second phase - i.e. music performance - is enabled to start. Before the design of this framework, two totally independent concepts were available:

- An *IEEE 1599 viewer*, namely an environment oriented to a multi-layer and synchronized musical experience. This software is able to present simultaneously information contents from multiple layers, allowing the user to enjoy them together and to choose the material to bring to front. The user is active in the choice of current materials (scores, audio tracks, video clips, etc.), and he/she can use standard navigation controls (start, stop, pause, change current position); however, from the performance point of view, the user can only experience already prepared materials.
- A meta-instrument parser, where a symbolic score is loaded and the user can interact through the interface of the musical instrument. The parser is not standard, since it is customized for the peculiar meta-instrument. Besides, it usually gets input only from the external controller and from a digital score representation. Consequently, other interactions with related materials is demanded to *a posteriori* processing of its output, which limits the expressive possibilities of the framework.

These two environments could be (and actually have been) implemented under different HW/SW architectures, and implementation details are not relevant for our proposal. For instance, IEEE 1599 players have been developed for multi-platform off-line fruition as well as embedded in Web portals. Similarly, there are some meta-instruments entirely implemented via software and others based on the communication between Arduino and Max/Msp environment. An example of the latter category will be provided in Section 4. Our idea is creating a unique framework where the two contributions can be mixed and integrated, in order to take advantage by both the approaches.

As regards the music meta-instrument, it can be any hardware or software device capable of sending computer-interpretable messages: MIDI controllers, external peripherals such as computer keyboards, graphical interfaces, and so on.

The function of the parser is interpreting both the IEEE 1599 and the controller input, producing a sequence of commands to drive the player. One of the key roles is disambiguating synchronization. As mentioned before, most contents in an IEEE 1599 document have intrinsic timing information, such as all audio and video tracks. On the contrary, in this context metronome is provided by the human player, so

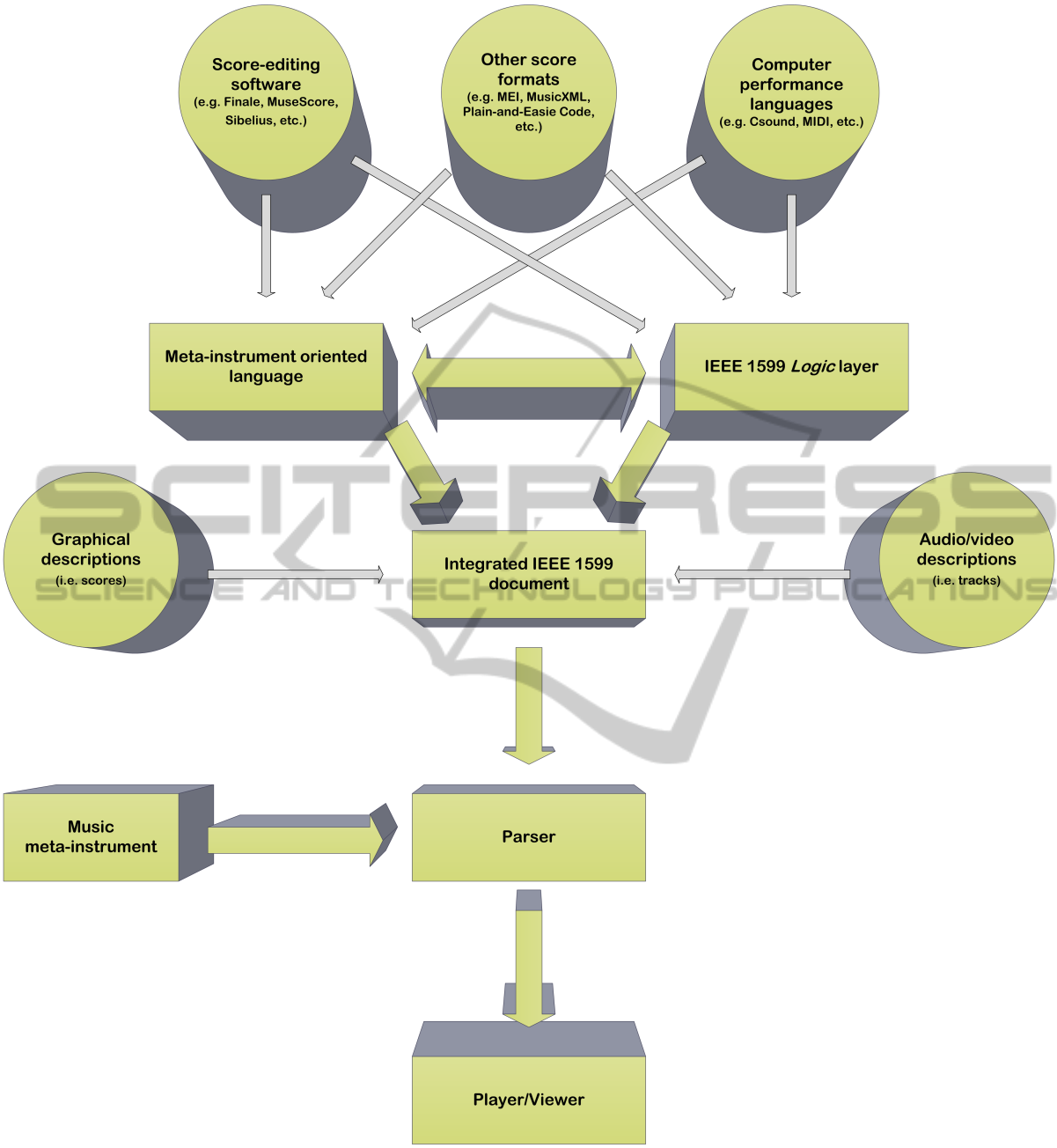

Figure 2: Process flow chart of the proposed framework.

the parser has to match human gesture with meta-instrument notation, and other contents must be consequently timed.

Figure 2 illustrates the proposed framework. The upper half corresponds to music encoding, whereas the lower half is about music performance.

4 CASE STUDY: THE METAPIANO

The metapiano is a musical meta-instrument made of only nine piano keys (Haury, 2013). It can be played with a few fingers, or even with one finger, as shown in Figure 3. The metapiano notation stores the notes to be performed by the musician. In practice, the mu-

sic is analysed in terms of its melodic, harmonic, and contrapuntal relations. Only notes' pitches and their relations are codified and stored digitally, according to *pianotechnie* rules (Haury, 1987).

This musical structure can produce music and sound by playing the metapiano's limited number of keys. The musician can instantly interpret music with his/her own style by applying his/her rhythm, tempo, articulation, accent, dynamic and agogic phrasing.

In this kind of meta-instrument pitch information is received from the score, and consequently reconstructed at parser level. The 9-key interface is provided only to allow more effective gestures. For instance, quick sequences of notes are easier to be obtained using many fingers, independently from the melodic contour. Similarly, a *legato* effect can be obtained only using at least two keys.

Experiments have shown that such an interface is extremely intuitive for complete beginners and inexpert players, who are not used to associate keys to sounds (Haury and Schmutz, 2006). On the contrary, for skilled piano players this abstraction is harder to be managed. However, the latter category is not the typical recipient of our initiative.

In order to apply the IEEE 1599-based framework to the metapiano case, a meta-instrument oriented language layer has been designed. This language is based on the syntactic and semantic encoding defined by Jean Haury. Starting from an XML encoding of the score, an integrated IEEE 1599 document is generated to feed the parser controlled by a musical meta-instrument interface. In this way, a 3-level hierarchy of music representation has been realized:

1. A low-complexity encoding for complete beginners, namely people unable to read music scores and to play any music instrument;
2. A medium-complexity encoding for learners, namely people who can read scores but with no instrumental skill;
3. Finally, a high-level encoding for musicians, namely people interested in improving their music abilities and experiencing new kinds of music interfaces.

Our approach can be easily extended to any other music meta-instrument, thanks to the extensibility of IEEE 1599 format.

5 CONCLUSIONS AND FUTURE WORK

In this work we have introduced at first the key features of IEEE 1599. Such a format allows a comprehensive description of music in all its facets, supporting multiple media encodings and keeping digital objects synchronized. Even if commonly adopted for education purposes, this format was never used before for music performance. The innovative idea is introducing a special controller acting as a music meta-instrument and designing a framework to integrate such a tool and the related notation with an IEEE 1599 parser/player.

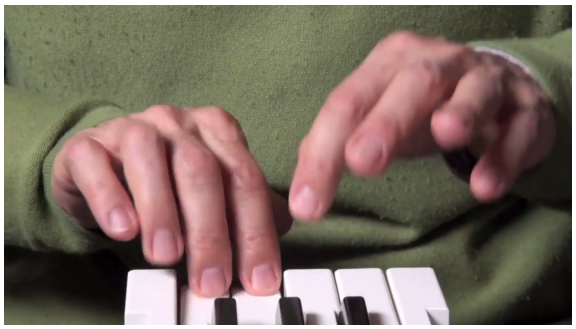

Figure 3: Jean Haury playing F. Chopin's *Étude Op. 10 No. 4* on his 9-key metapiano.

Future work will concentrate on a re-engineered implementation of the framework, extensive tests conducted on impaired children and piano beginners, and the extension to meta-instruments other than Haury's metapiano.

ACKNOWLEDGEMENTS

The authors gratefully wish to acknowledge the researchers who contributed to this work. In particular, we want to thank for their support: Jean Haury, the inventor of the metapiano, Pierre Castellotti, an expert in the field of meta-instruments and musician-to-machine interfaces, and Stefano Bruni, who implemented an automatic generator and translator of metapiano notation.

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