Developing Intuition in Engineering Education: New Technology To Capture Structures in Music

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***Abstract* — Traditional engineering education, with its focus on formal disciplines such as mathematics and natural sciences, has been adequate for many aspects of *problem solving.* However, new cultural and economic challenges in the globalized world require the ability to see problems *as a whole* and to compete thanks to the ability of *problem finding*, which requires the kind of intuition and creativity generally associated with *art* and *aesthetics.* This article claims that thanks to the development of new technology and tools in *musical computer science*, such as Standard IEEE P1599 developed by the authors, it is possible to integrate *creative training* in a formal curriculum, thus favoring the development of *intuitive skills* among engineering students.**

Keywords – intuition; engineering education; music; musicology; symbolic encoding.

Introduction

1 Historical considerations

Contemporary engineers must be hearing loud complaints from machine buyers, whether frustrated users or angry housewives, about how silly, bad looking or counter-intuitive a certain human-machine interface has been designed. Unlike manufacturing of the past, today the quality of a Web page does not depend on how well a programmer is fluent in HTML, but on the aesthetic appeal of its graphics and the accessibility of its functions. Thus, criteria once viewed as sacred assets in the engineering of yesterday, such as *accuracy*, *precision* and *reliability*, are often liabilities toward a successful product, in which what counts is ease of use, immediacy and intuitive understanding of the different functions.

Unlike in the past, when engineering was considered a noble profession – with heroes by the name of Edison, Bell and Berliner – contemporary practitioners of the art are often reduced to the level of cogwheels in large hierarchical organizations that are never put in question. Yet, science has not advanced thanks to the kind of simple hierarchies, inferences and cause-to-effect relationships favored by technical schools, but practically always through quantum leaps.

This was well known at the time of Italian Renaissance, when Humanism put back *man*[1] at the centre of focus. Thus, it was not uncommon to be both a scientist and an artist, as the cases of Leonardo and Brunelleschi illustrate. This union has been somewhat shadowed in the 19th century by the attempt to go beyond the analytical

[1] English being a sexist language, we will use those terms, *man*, *his, he,* for simplicity, intending to include both men and women.

precision of the encyclopedia of the enlightenment, and give back the proper weight to subconscious drives. However, this has created an apparent dichotomy between the undisciplined, inspired artist and the cold scientist who proceeds step by step.

Today we know that this myth is false. Composers, for instance, do go through a deep training to understand complex *musical forms* and develop the ability to *lead musical parts* and *orchestrate* them, processes similar to a computation[2], often involving *backtracking*, as in the computer language Prolog. On the other hand, mathematicians or physicists reach the solution of a problem thanks to inspiration: Poincaré stated that a correct formula is *beautiful*, Srinivasa Ramanujan is said to have stared at a formula and corrected it until it seemed right[3]. Einstein stated that he "saw" the theory of relativity by imagining to sit at the edge of a traveling light ray, to witness how it bends in space[4] – in fact, Einstein did not have a great reputation as a formal mathematician[5]. In all these cases, mathematics is an a-posteriori formalization of something already conceived, which has to be put in a common language, much as I put in writing these thoughts.

Relationships between the humanities and the natural sciences, including engineering, has had a revival in the last decades after the start of *Cognitive Science* [1] and especially *Artificial Intelligence* [2]. Maybe the most encompassing example of this trend is the book *Gödel, Escher and Bach* [3], which won the Pulitzer Price in 1980. Among others, it focused on so-called *strange loops*, which have been known for millennia[6], namely, the limits of logic as shown by *Gödel's Theorem*, *Russell's Paradox* and *Turing's Undecidability of the Halting Problem*, and also in the arts, the music by Bach and the surrealist paintings by Escher and Magritte. They generally occur together with *self-reference*, as in programming with the language LISP. Therefore, strong similarities exist in art, in science and in nature, as already intuited by Baudelaire [4], and the mind is self-referencing!

Of a different kind is *Zen or the Art of Motorcycle Maintenance* [5], which focuses on philosophy. The author describes the search for a philosophical entity, which he calls *Quality*, in a motorcycle journey from Minneapolis to the West Coast of the United States. Several journeys are intertwined in the story, that on the motorcycle, the relationship with his young son, and the rediscovery of the previous self of the author, Phaedrus, when he was searching for the Quality, just before he was interned in psychiatric hospital. A sentence such as "I was thinking how a Sophist would contradict Aristotle while, with a roar, I switched down into second gear on my Harley entering Dakota Territory"[7] would be typical of such relationships.

2 The consequences of an intuitive approach in Engineering Education

And how does this affect the contemporary engineer? In a world with growing globalization and fiercer competition, where market access requires new paradigms, the ability is needed of viewing a problem as a whole. At the same time, increasingly

[2] Even jazz improvisers develop a "logical" sense of sentence construction and balance, see e.g. Charlie Parker and John Coltrane

[3] The remarkable thing is that sometimes the formula was wrong!, as described in [4].

[4] As reported by Mike Cooley, International Conference *The Culture of the Artificial*, Lugano, October 12th, 1990.

[5] Private conversation with Prof. Banesh Hoffman, Queens College, City University of New York, 1980. Prof. Hoffman was Einstein's mathematician.

[6] For instance, "Epaminides, Cretan, states: all Cretans are liars".

[7] Sentence invented by this author

complex systems, such as computer hardware, software and networks, require better analytical tools than simple cause-to-effect models. Fortunately, new technology, obtained with progress in Computer Science, comes to rescue with new tools to develop one's unified view of a problem, thanks to ***music*** and its *computational treatment*.

2.1 Progress in Music and Computer

Music has often been recognized, in advanced engineering curricula and manager courses, as the discipline capable of developing the kind of *intuition* needed to solve complex problems. It has several levels of *structures* and sets of *rules*, but the models are not simple. Similar to language, there is no objective meaning associated with musical events, though there is often a consensus on the *overall message*.

Even though early experiments to *formalize* certain aspects of music can be attributed to *Mozart*[8] and *Haydn*[9], not to speak of Babylonian clay tablets, computer science and engineering curricula have often neglected music and musicology. After the success by the Bell Telephone Laboratories[10] in sound synthesis, this has changed in the last decades – e.g., with the establishment of the *Technical Committee on Computer Generated Music* in the IEEE CS, the founding of laboratories such as *IRCAM*[11] in Paris, *LIM* in Milan, and *CNMAT* in Berkeley.

2.2 The Symbolic Representation of Music

Over a century ago, *music fruition* meant the purchase of a score from which to play. While reserved to those who were able to play an instrument, this favored a certain familiarity with music, which helped develop *musical knowledge*.

With the advent of the phonograph and of the gramophone, music enjoyment has meant the acquisition of an encoded device to *passively absorb the sound*. While this has made the pleasure of music available to everybody[12], the effort to understand *how music is built* has been almost totally lost. This has not improved with the advent of *binary*, *closed and unreadable audio standards* such as WAV, MP3, etc.

However, *audio is not music*. For a music lover, the musical experience is the act of *entering a new world*, *living an experience, understanding a narration* and *recognizing images and landscapes*, maybe of investigating how the whole is built.

To this end, music must be represented with something that goes beyond *unreadable, binary standards for audio*. Musical *non-audio layers* have to be represented as well, in human-readable form such as *symbols* and *characters,* as it has always been for a *music score* (in classical music), or in a *notation* such as the *harmonic grid* (as in jazz), or other as in Non-Common Music Notation.

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[8] *Würfelspiel*, to be found for instance in "Musica ex machina", Einaudi, 1963

[9] Published among others as "Gioco filarmonico", Ricordi, 192?.

[10] Just a few examples of discoveries at Bell Labs.: *electromagnetic recording* in the 1920's, the *talking movie* in 1926, the *transistor* and solid-state electronics in 1947, the *UNIX Operating System* in the 1970's.

[11] Example of IRCAM's known successes are: the *synthesis of the voice* of castrate Farinelli in the movie by the same name; the English rendition of actor Gérard Depardieu's voice thanks to formant analysis and synthesis.

[12] It also helped the development of arts for which the value is not in the music score, e.g. *Afro-American jazz*.

The idea of representing music with symbols is not new. If we consider music notation, it goes back several centuries, in the West and elsewhere, and for computer applications, at least several decades, as shown by the *Plaine-And-Easie Code* [6] and *DARMS* [7].

2.3 The New Standard IEEE P1599

The new technology of ***IEEE standard P1599*** [8], with its emphasis on *symbolic music representation*, opens up new worlds of possibilities. In it, the language *XML* is used, which allows inherent *readability*, *extensibility* and *durability.* This technology represents the basis for applications that allow a full musical experience. The standard recognizes the existence of different *layers* to represent music: *general* – with information about the piece – *structural* – music objects and their relationship – *notational*, for the graphical representation the score – *performance* – with all information for the automatic rendition of a score – *audio* and *video* – in any possible encoding. Not all layers have to be present for a given piece of music.

2.4 Examples of applications to realize

Representation of music in symbolic form allows the realization of countless IT systems that transform passive listening of music into the discovery of its meaning and of how it is made. Such examples are: **An opera:** See the play on the screen, hear the music, see the score, read the libretto, choose excerpts from alternative renditions; **A piece by a jazz Big Band:** The harmonic grid is displayed and the name of the soloist pops up at the beginning of each solo; **A fugue:** The theme is highlighted aurally and graphically as it gets passed among the different voices; **Music with a "program" or story**: Examples are Prokofiev's *Peter and the Wolf*, Saint-Saëns *Carnival Of the Animals,* Vivaldi's *Four Seasons;* **Indian classical music:** the scale of the *raga* is shown and the melodic development is highlighted with a diagram; **A piece of several drums, as Cuban Guaguanco:** a graph shows that the various hits do not fall exactly on the beat; **Ease of query:** music pieces with characteristics, notes, or other – for instance, all pieces utilising the lowest note of a grand piano; **Preservation of the music heritage from the past,** as in the work by an author of this writing [9]; **Books about the making of a piece or the work and life of an artist:** For instance, the record *Kind of Blue* by *Miles Davis* [10].

These examples illustrate that *there is no limit to what can be realized* with the symbolic representation of music, and that the world of engineering education is just waiting for applications.

3 Demo #1: score, chords, music piece played by the composer, movie, historic documents: Jelly Roll Morton's "King Porter Stomp"

The encoded pieces are *King Porter Stomp, 1924* and *King Porter Stomp, 1939*, two scores of the once famous composition by American pianist *Jelly Roll Morton,* or *Ferdinand Joseph La Motte*, 1889-1941. When the piece starts, several *synchronized activities* execute in real time: on the *score window*, the running cursor indicates what is being played, and the user can move to another point in the score while the other windows instantly adjust. The *XML window* shows the encoded events, and the *chords window* displays the elements of the harmony of the piece.

4 Demo #2: no score, harmonic grid, identification of soloists: "Crazy Rhythm", Coleman Hawkins and his All StarJam Band

The demo is meant to show how jazz improvisation is to be understood. The reference is the *harmonic grid* represented at the centre of the screen. The symbols in each *square,* which represents a measure with 4 bars, are part of a conventional notation for jazz chords [11], a theory which could be the object of another teaching tool.

This is a jam session that occurred on April 27, 1937, with four well-known jazz saxophonists, namely, American top jazz musicians Coleman Hawkins on tenor saxophone and Benny Carter on alto, both living in Europe at the time, and Frenchmen André Ekyan, alto, and Alix Combelle, tenor. Benny Carter quickly put together a head arrangement for *Crazy Rhythm*, showing the part to each instrumentalist.

Upon selecting the piece and starting it as described in the preceding paragraphs, the user hears the ensemble and sees a picture of all saxophonists, then each soloist pops up as the music proceeds. The user can click to another soloist to let the music jump ahead to the same bar of that solo. The difference in *style* between the different soloists and between alto and tenor saxophone is made obvious.

5 Demo #3. Music with a program: Antonio Vivaldi's "The Hunt" in "The Four Seasons"

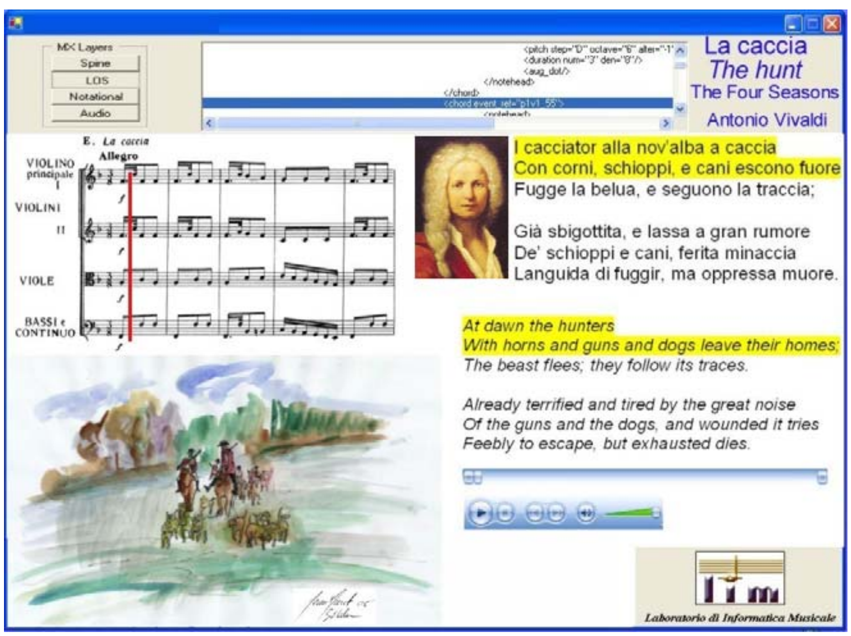

Figure 1 – Demo #3, "The Hunt" from Vivaldi's "Four Seasons"

Not everybody is aware that Antonio Vivaldi's *The Four Seasons* comes with sonnets which explain section by section what goes on in the music. In the *Hunt* in *Autumn*, musical excerpts refer to the hunters riding, blowing horns, to the running fox, hunters shooting and dogs barking. Then the fox is hit and dies.

In the browser, each scene is represented by a professional painter. Figure 1 shows the original score, with the corresponding painting and the verse in the sonnet. The user can click on: score, picture, and sonnet, to jump to different parts of the piece.

6 Conclusion

Musical education requires several years of study to master concepts such as *harmony, counterpoint, composition, orchestration, musical analysis* and the like. While these disciplines will be left to the serious music student, the ability of *seeing how music is done* is now put at the disposal of interested listeners, allowing them to *develop an understanding beyond standard engineering logic*, and therefore to benefit from *another vantage point for the development of new ways of confronting technical problems.*

It is therefore high time that engineering education borrows some techniques from the humanities and the arts. This is something usually resisted by engineering students who think *they have better things to do*, but this article claims that, thanks to new computing technology and symbolic representation, the hitherto inaccessible world of music becomes available and the study of music becomes a pleasure, taking a listener from enjoyment to education and to a complete engineering training.

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