Sharing (musical) time between machines and humans:
simultaneity, succession and duration in real-time computer-human musical interaction

Jean-Louis Giavitto

The functional approach to AI has focused on the ability to provide a computer the cognitive capabilities usually attributed to humans: translating a text, recognizing an object in an image, playing chess, planning a route, etc. Even if perception and actions have been largely considered, cognitive capabilities related to the apprehension and the organization of time have been less studied. Music is a prime area to address these issues. In all written forms of music, the act of music composition is a choreography of events and expectations in time to allow sophisticated continuous interactions among musicians. This powerful effect is the result of intrinsic combination of strong language formalisms (for authoring music) and performance mechanisms that allow synchrony, real-time coordination of actions and robustness of expected results in ensemble music.

Bringing such capabilities to computers and providing them with the ability to take part in musical interactions with human musicians is an excellent workbench to investigate and to test, from an experimental viewpoint, several temporal notions.

This presentation focuses on the various temporal notions put at work in the *Antescofo* system. This system couples a *listening module* and a *domain specific programming language*. It is used by music composers, and more generally by interactive multimedia designers, to specify and to implement *augmented scores*, *i.e.*, temporal scenarios where electronic musical processes are computed and scheduled in tight interaction with a live musician performance[1].

Interaction scenarios are expressed at a symbolic level through the specification of musical time in the score (musical events like notes and beats in relative tempi) and the management of the physical time of the performance (with relationships like succession, delay, duration, velocity of the occurrence of the events on stage). During the performance, human performers "implement" the instrumental part of the augmented score, while the language runtime evaluates the electronic part with the help of the information provided by a listening module, to control and synchronize the electronic actions with the musical environment.

These two main phases of the usual workflow of written music, *composition* and *performance*, relies on two different notion of time reminiscent of the distinction pointed by John Mc Taggart [7]: the *B-series* of the "deferred time" specified in the score during the authoring phase and the *A-series* of the real-time relationships occurring on stage during the performance when a score is interpreted.

Succession and *simultaneity* are the two forms of the perception of the interval in music [9]. It is also two of the three relationships classically used to analyze time and the basis of *event-driven*, or reactive, systems in computer science. But *Antescofo* is also a *timed* system [4] tacking into account the relationships of delay and duration in the score. As acknowledged by many philosophers [8], duration is irreducible to succession and simultaneity: it cannot be abstracted by a starting and an ending instantaneous event. This leads to the notions of *striated* and *smooth*

[1] Used in the mixed music piece produced at IRCAM, *Antescofo* has gained a wide audience attracting composers in contemporary music such as Pierre Boulez, Philippe Manoury, Marco Stroppa or Emmanuel Nunes which have used the system for the creation of new musical mixed pieces and for their performances by the Los Angeles Philharmonic Orchestra, the Berliner Philharmoniker, the Orchestre de Radio France, *etc.* Videos of actual performances and additional informations are available on the project web site `http://repmus.ircam.fr/antescofo`.

time exemplified by Pierre Boulez in music [3] but also to the notion of *inner tempo*, drawing near to the concept of duration developed by Henry Bergson [2, 9].

The timing relationships (duration, succession, simultaneity) between events denoted in the score are *relative* (to each others), *virtual* (the timing relationships expressed at the level of the score will be instantiated during the performance) and *undetermined* (several performances comply with the same score). During live performance of a music score, musicians instantiate the high-level processes denoted in the score by musical gestures. At this point, the durations and delays become physical time (measurable in second). Nevertheless, events with the same relative duration in a score (and in different positions) do not necessarily lead to the same duration during the execution and vice versa. Their value depends highly on the performance, individual performers and musical interpretation strategies such as stylistic features that are neither determined nor easily formalizable: the tempi, accelerations, rubato, etc. are personal choices that will vary in every performance. The notion of internal tempo may appear problematic for at least two reasons: first, it leads directly to the questionable notion of "speed of time" and secondly, it calls for an actual measurement in order to relate continuously the different and subjective time frames. We will explain how *Antescofo* faces these two problems in an effective way.

Time is a resource and programmers organize it in programs through the figures of succession, simultaneity and duration. This analytical grid remains however limited because computers increasingly interact with us and our experienced time. Our perception of the duration, our sense of the passing of time, must be taken into account to achieve a fluid and seamless interaction between human and machines. *Antescofo* achievements show that this goal is not out of reach. But then, the computer scientist has to confront other dimensions of time as movement, memory, expectation, passage, anticipation, becoming...

References

[1] Matthew Bennett, Michael F Schatz, Heidi Rockwood, and Kurt Wiesenfeld. Huygens's clocks. *Proceedings: Mathematics, Physical and Engineering Sciences*, pages 563–579, 2002.

[2] Henri Bergson. *Time and free will: An essay on the immediate data of consciousness*. Courier Dover Publications, 2001.

[3] Pierre Boulez. *Penser la musique aujourd'hui/Boulez on Music Today*. Paris Gonthier 1963/Harvard University Press 1971, 1963. trans. S. Bradshaw and R. Rodney.

[4] Hermann Kopetz. Event-triggered versus time-triggered real-time systems. In *Proceedings of the International Workshop on Operating Systems of the 90s and Beyond*, volume 563, pages 87–101, Dagstuhl Castle, Germany, July 8-12 1991. Springer.

[5] Edward W. Large and Mari Riess Jones. The dynamics of attending: How people track time-varying events. *Psychological Review*, 106(1):119–159, 1999.

[6] Tim Maudlin. Remarks on the passing of time. In *Proceedings of the Aristotelian Society*, volume 102, pages 259–274. JSTOR, 2002.

[7] John Ellis McTaggart. The unreality of time. *Mind*, 17:456–476, 1908.

[8] Lluis Vila. Formal theories of time and temporal incidence. *Foundations of Artificial Intelligence*, 1:1–24, 2005.

[9] Bernd Alois Zimmermann. *Intervall und Zeit: Aufsätze und Schriften zum Werk*, volume 6361. Mainz, Schott, 1974.