Foot-tapping: a brief introduction to beat induction

As an example, have a look at the following pattern of lines and dots:

\[
\begin{array}{ccccccccccc}
... & ... & ... & ... & ... & ... & ... & ... & ... & ... & ...
\end{array}
\]

Do you see any emergent structure? Probably not. When you would listen to it, though, (e.g., the pattern being played from left to right, with every line being a 16th note and every dot a 16th rest) you would quickly hear a regular pattern—the beat—and could probably easily tap your foot along with it.

This relatively simple cognitive task is called beat induction or foot-tapping. Beat induction is a fast process. Only after a few notes (5-10) a strong sense of beat can be induced (a "bottom-up" process). Once a beat is induced by the incoming material it sets up a persistent mental framework that guides the perception of new incoming material (a "top-down" process). This process, for example, facilitates the percept of syncopation, i.e., "to-beat" a beat that is not carried by an event. However, this top-down processing is not rigidly adhering to a voice-established beat perception, because when in a change of meter the evidence for the old percept becomes too meager, a new beat interpretation is induced. This duality, where a mode needs to be able to infer a beat from scratch, but also to let an already induced beat guide the organization of new incoming material, is hard to model.


Interactive computer music systems
Interactive computer music systems make some interesting additional demands with respect to those mentioned above (see, e.g., Boulanger, 1990). First, they have to perform in real-time, which means that they have to be efficient enough and that they have to deal with the musical material incrementally (i.e., while the input is processed). They also have to deal with real performance data (containing expressive timing, performance errors, etc.), thus these systems have to be robust (i.e., they should recover gracefully from errors), they have to deal with instruments that exhibit some response delay (for acoustic instruments such as piano’s or short), and to do this, they need careful temporal planning (i.e., scheduling). Most of the design issues seem to be related to cognitive models, problems that can not be ignored when aiming at a realistic cognitive model of beat induction.

Unfortunately, neither cognitive or technological approaches have been able to arrive at a general, robust beat extraction method. The big challenge seems to lie in the unification and generalization of the existing, partially successful theories, since they all, apparently model at least one valid aspect of beat induction. We hope that the special ICNC 1994 paper session on foot-tapping and the current article may be a contribution towards this goal. To enable the audience to compare their own foot-tapping with that of the presented models, some of the computational models will be demonstrated with on-line computer implementations connected to a mechanical footcapper (see Figure 1).

Peter Denan & Heiko Söding

References (shared by papers in this chapter)

Foot-tapping 78
ICNC Proceedings 1994