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Auditory information processing: the computational approach

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Computational models of the auditory function have long been pursued and used for compact and predictable description of both perceptual and physiological responses to auditory stimulations. From a physiologist's point of view, building a computational model is a major part of the functional description of a biologically realised system. From an engineering approach, mathematical models of biological systems form the base for building applications of major importance in the fields of signal processing (such as compression, denoising, speech and voice analysis and recognition, etc), assistive technology, etc.

Modeling of auditory perceptual phenomena has a long tradition starting (possibly) in the ancient era and reaching more efficient scientific approaches at the times of Helmholtz, Bekesy, and others. Recent advances in electronics and computers had a major effect on the field of auditory computational modeling, together with more precise physical and physiological descriptions of the mammalian auditory organ.

A major aspect of auditory computational models is feature extraction, referring to their ability to describe physical sound qualities with mechanical or neuronal auditory processing terms. Informational approaches to coding are based on feature extraction.

To accomplish such a task, we present the major peripheral parts of the auditory chain (outer, middle and inner ear), and describe various quantitative approaches that have been proposed and integrated into computational models. Special focus is given on the hair cells' functional description, relating their operation and statistical description approaches to specific auditory phenomena.

Major indices or representations derived from computational models (such as firing rate and patterns) are discussed and related to more general neural computing schemes.

From a perceptual point of view, various computational schemes proposed for the description of important psychoacoustical terms (such as pitch/timbre perception, masking, e.t.c.) together with prompt presentations of relevant experimentation, are also presented and discussed (e.g. Lyon, Shamma, Patterson). Temporal, spatial, and spatiotemporal approaches' differentiation of peripheral auditory processing is made clear, and hints are given for possible processing taken place in higher nervous system centers. This discussion offers the chance to introduce Prof. Langner's and Dr. Schneider's presentations on information processing in the central auditory system.

Finally, some results of recent experimentation on specific perceptual tasks regarding timbre perception of musical sounds are presented, and cues are discussed in the context of various computational schemes. More specifically, we describe motivation, methodology, and analysis of computational experimentation on a micro-timbral discrimination task. We also relate our analysis to evidences by psychoacoustical experimentation evidence. The possibility of DSP implementation of auditory models in musical/engineering applications is also considered.