Closing the Loop of Sound Evaluation and Design

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Abstract

Despite being a promising and lively playground, sound design is not a discipline as solid and established as visual or product design. We believe that the reason is to be found in the lack of design-oriented measurement and evaluation tools. The European project CLOSED (Closing the Loop Of Sound Evaluation and Design) aims at providing a functional-aesthetic sound measurement tool that can be profitably used by designers. At one end, this tool is linked with physical attributes of sound-enhanced everyday objects; at the other end it relates to user emotional response. The measurement tool will be made of a set of easy-to-interpret indicators, which will be related to use in natural context, and it will be integrated in the product design process to facilitate the control of sonic aspects of objects, functionalities, and services encountered in everyday settings.

1. State of the Art/Design

Art creation has historically been a feed-forward process in which an idea, conception, or intuition precedes the actual production of artefacts. Feedback can be found and used in several artistic contexts, but it is rarely functional to artefact development. The revolutionary contribution of the Bauhaus school in the early 20th century was to situate visual art in an iterative process incorporating analysis and prototyping, thus closing the creative loop and founding the discipline of design. What distinguishes design from art is the role played by the evaluation of functional qualities of artefacts, with the general aim of improving daily life. Measurement is the key component in any feedback control loop: the design loop is an iterative process where the input from the initial idea is iteratively compared with results fed back through the evaluation block.

Another key characteristic of some great design schools of the twentieth century (Ulm, Chicago) was to encourage continuous confrontation with science and technology, and to formalize the design education process through sets of exercises of *basic design* [1], where the student was actively engaged to make a composition that solves a specific communication or use problem, under very strict constraints. As an example of exercise in visual design, a student may be asked to produce an apparently convex surface just by painting circular elements on it.

There has been about a century of more or less successful attempts to close the loop in visual design of industrial products. Today, some companies like Alessi that give high value to visual communication effectiveness base their product design cycle on sophisticated, semantics-based visualization and modelling tools. Due to the limitations of purely visual design, the products can often exhibit inconsistencies when their tactile or sonic qualities are evaluated. While tactile and haptic information is gradually entering the design process, functional sound continues to be a largely unexplored territory in design practice. So, despite a history of craft of musical sound design, which extends to ancient times, nowadays some people claim that sound design does not exist as a discipline yet [2]. Exception may be found today in sound for cinema, where sounds are crafted to enhance or surrogate visual experiences, or in sound for alarms, where auditory guidelines have been designed and validated to communicate emergency [3].

During the last fifteen years, many research projects have addressed sound quality measurement. Noises emitted by domestic objects (e.g. light switches, vacuum cleaners, and coffee machines) or equipment (e.g. car motors, air conditioners, and windshield wipers) can now be characterized and evaluated by psychophysical methods, by judgment on nominal bipolar scales (semantic differentials), and by psychoacoustic measurement tools. Such methods and measurements are well suited to characterize the acoustic annoyance or preference [4], but fail to account for emotional and cognitive responses related to the functional-aesthetic aspects of a product. It is believed that most classes of everyday sounds have emotional connotations, which precede their cognitive interpretation. These emotional connotations will influence the way a listener perceives a given sound [5]. A systematic approach to affective reactions to sounds would further increase our understanding and ability to predict human responses to new everyday products enhanced by sonic properties. It takes a fraction of a second for a listener to have an emotional response to a new object, and on that basis to approach positive and avoid negative objects. This is "the unbearable automaticity of being" [6]. Emotions allow to make quick decisions about the world, while cognition permits to interpret and understand it. Further, studies have shown that the emotional system changes how the cognitive system operates [7]. Thus, measurement of emotional sound qualities of a product may provide access to the characterization of beauty and function in a sound design process.

Our present knowledge about everyday sound is insufficient where relations between physical characteristics and perceptual descriptions are concerned, especially with regard to functional-aesthetic qualities. Research in psychoacoustics has largely focused on the physiology and neurology of hearing, and on the determination of perceptual attributes such as pitch, loud-

ness, duration, or timbre. Surprisingly, with the exception of a few studies [8, 9], very little psychological research has addressed what we hear of events in the world and how we hear them. Of late, several studies have focused on the perception of source attributes such as excitation pattern and structural invariants (like size, shape and material) instead of sound attributes [10, 11, 12]. Results have shown that people perceive quite well the physical features of sound sources using sound. Recently the European project "the Sounding Object" further expanded this body of experimental evidence and used it to design physically-based sound synthesis modules for everyday acoustic phenomena [13]. In the field of audio signaletics, most sound designers have their own recipes to make samples that convey a certain meaning, which we could call auditory function: for example cross-road sound signals are different among several countries. Study of everyday sounds could help to extract auditory attributes and patterns in order to create unambiguous sounds to fulfills specific functions. Recommendations for the designers have to be informed by perceptual results.

Along another research line, pattern analysis techniques [14] (e.g. Independent Component Analysis (ICA)) have made significant progress in facilitating the extraction of perceptually based sound descriptors [15, 16]. Actual progress in this area was possible thanks to the availability of a body of knowledge in auditory perception and scene analysis. What is missing in current analysis tools is the capability to extract functional and aesthetic information. These may come by linking pattern analysis techniques with results of psychophysical experimentation, in such a way that mathematical models, generalizations, and classifications are conducted on functionally selected sound databases and on parameter sets of synthetic sound models.

The design of product sounds should consider the most advanced trends in product design, especially where interaction is a key issue. Human-centred design is an integrated and iterative product and service design methodology, innovated recently at Sapient and extended in European research projects (Design for Future Needs) [17, 18]. It is founded on understanding users needs, and on the participatory integration of users into the design process, through simple prototyping and context-based experience assessment. Its application in sound design is almost unknown probably due to a lack of suitable examples and prototyping tools. However, the emerging possibility of augmenting products with sensors and dynamically responsive synthetic sounds opens up wide new horizons in already established design practices. These may increasingly be expected to rely upon experiment and simulation, or mathematical modelling, as integral to the design loop.

2. A Sound Approach to Sound Design

It is asserted that the key to closing the sound design loop is the availability of suitable measurement tools and criteria. This is indeed the kernel objective of the CLOSED project, and it is pursued by structuring the project itself as an iterative design process.

Interaction designers will identify fertile scenarios and existing examples from everyday contexts (such as the kitchen) that are ripe for sonic improvement, and a number of design concepts for product sound enhancement are developed. A set of interactive, sound-enhanced prototype artefacts are going to be produced to enable exploration of a region of the functional-aesthetic design space. The sounds generated in the course of physical manipulation of the artefacts will depend upon continuous input captured from the gestures of the user. These artefacts will be abstracted and removed from true functionality, but designed so that each one is representative of the salient physical, interactive, and sonic features of an interesting class of sound products. This approach is in line with classic basic design practices, here extended to deal with interactive artefacts. Contributing products are selected from both the active (food processor, kitchen sink) and passive (wine bottle, wire whisk) behavioral categories. Interactive synthesis models for characteristic sounds are going to be interchangeably embedded in the prototype artefacts, and the functional-aesthetic qualities of the sound artefacts will be evaluated using ethnographic and human-centred design methodologies. Subsequently, a set of structured psychological experimental investigations will permit to evaluate the functional-aesthetic qualities of the products by means of the emotional and cognitive responses of people interacting with them, taking into account a range of use contexts. The results of these experiments will be used to validate and refine the measurement tools that will be engineered to infer salient features relevant to human emotional response to the utilized sound models.

The potential for prediction and inference of machine learning technology becomes effective if a small change in a feature causes only a small change in a corresponding perceptual attribute (smooth mapping). Under the latter condition, classifiers, predictors, and visualization tools will be developed. Features that significantly determine emotional and functional-aesthetic sound attributes are going to be singled out through supervised learning, such as regular discriminance analysis, wrapper, and filter methods. Such features can be found at the signal level, but will become fully usable as design parameters when they are linked to sound models, possibly physically-based. In this way, sound-augmented artefacts will be realizable by tight coupling of sensors and sound synthesis parameters, and controllable by navigation in the spaces provided by mathematical models developed via machine learning. Sounds can be classified w.r.t. perceptual attributes. Some of these attributes can be predicted for a given sound pattern. Such a predictor facilitates the design of sounds with a presupposed sound quality. Visualization tools, such as correspondence analysis [16] and non-linear methods (local linear embedding, isomap), yield a perceptually relevant space. If sound patterns are mapped onto such a space spanned by relevant attributes, the distance among the projected sounds provides a salient measure for the similarity of sound patterns.

The flexibility required by this iterative process is facilitated by an array of sound synthesis building blocks that are being elaborated to permit to mold the sonic appearance of objects in which they may be embedded, their sound quality being tailored using the new measurement tools to produce particular affects that it is desired to explore.

Previously, aesthetics of sound and music has been identified as an optimum value between high (too boring) and low (too complex) entropy [19]. This rather trivial statement falls short in adequately accounting for aesthetics as a sensitively balanced optimum of several factors, revealing the difficulty to formalize and measure aesthetics. However in the situation of sound design (as opposed to music) aesthetic questions can be - to a high degree - reduced to tractable problems, since the semantics of an object can be explicitly specified. In some instances, the function of an object is clearly defined; e.g. a kitchen knife is for cutting, it has to be sharp. Context comes into play as the association with natural or other previously existing prominent sounds. Of interest for sound design is the fact

that sound carries various properties that give physical, kinematic, and procedural information about the source. Physical invariants of the sound source can be singled out: size, weight, state of aggregation, material, and surface. Kinematics of sound sources can be heard as well: acceleration, deceleration, abrupt stop, impulse. Another aspect is the learned causal relation inherent of the consecutive steps in a process. This can be expressed by rules or by a simple grammar. These physical "synthesis parameters" are difficult to estimate statistically with high accuracy. However, perception cannot precisely account for these features either. Properties of objects and interaction processes give rise to an actual perceptual equivalent that only roughly corresponds to the factual physical reality. The perceptual entities and their level of accuracy can be achieved by statistical methods.

3. The Present/Future

The CLOSED project aims at providing a scientific basis and tools for the realm of sound design to connect beauty and function based on phenomenology, system modelling, mathematics, psychology and neuroscience. In three years from now it is expected that a discipline of product sound design will start to emerge, to be practiced, and to be taught. Indeed, designers are aided by the increasing availability and affordability of technologies that change the appearance of objects; e.g., electronic ink, dynamic actuators, etc.. Now it seems that the sonic appearance of objects is the most likely to become malleable and dynamically changeable in the near future, as microprocessors and loudspeakers can be already embedded into many objects. Examples of this kind are already on the market. Consider, for example the Apple Mighty Mouse. It has an embedded piezo loudspeaker that serves to nearly transparently augment the rolling sound of the user's two-dimensional scrolling actions, which, although beneficial for interaction, most users are not aware of. Similarly, the new controller of the Nintendo Wii game console embeds gyroscopic and acceleration sensors coupled with an embedded loudspeaker. In this way, perception and action are tightly coupled via direct manipulation and acoustic/vibratory feedback localized where the action is [20]. For istance, playing virtual tennis is much more engaging with this kind of controller.

These new technological amenities open wide and serious design problems. As far as sound is concerned, the CLOSED project addresses these problems via experimentation and measurement.

4. References

[1] M. A. Garito and G. Anceschi and M. Botta, editors. L'ambiente dell'apprendimento - Web design e processi cognitivi. McGraw-Hill Italia, 2006.

[2] D. Rocchesso and P. Polotti, There is no such thing as sound design. Proc. International Computer Music Conference, Inspirational Ideas, 2005.

[3] N.A. Stanton and J. Edworthy, editors. Human Factors in Auditory warnings. Ashgate Publishing, 1999.

[4] P. Susini, S. McAdams, and S. Winsberg, A multidimensional technique for sound quality assessment, ACUSTICA - acta acustica, 85, 650-656, 1999.

[5] D. Västfjäll and M. Kleiner, Emotion in Product Sound Design. Journes du Design Sonore, Paris, 2002.

[6] J.A. Bargh and T.L. Chartrand, The unbearable automaticity of being. American Psychologist, 54, 462-479, 1999.

[7] N. Tractinsky, S.-K. Adi, and D. Ikar, What is Beautiful is Usable. Interacting with Computers, 13, 127-145, 2000.

[8] J.A. Ballas, Common factors in the identification of an assortment of brief everyday sounds. Journal of Experimental Psychology: Human Perception and Performance, 19, 250-267, 1993.

[9] W.W. Gaver, How do we hear in the world? Explorations in ecological acoustics. Ecological Psychology, 5, 285-313, 1993

[10] G. Canévet, D. Habault, S. Meunier, and F. Demirdjian, Auditory perception of sounds radiated by a fluid-loaded vibrating plate excited by a transient point force. Acta Acustica - Acustica, 90, 181-193, 2004.

[11] S. Lakatos, S. McAdams, S., and R. Caussé, The representation of auditory source characteristics: Simple geometric form. Perception and Psychophysics, 59, 1180-1190, 1997.

[12] S. McAdams, A. Chaigne, and V. Roussarie, The psychomechanics of simulated sound sources: Material properties of impacted bars. J. Acoust. Soc. Am., 115, 1306, 2004.

[13] D. Rocchesso, R. Bresin, and M. Fernstrom, Sounding objects , IEEE Multimedia, 10(2): 42-52, 2003.

[14] Y. Visell, Spontaneous Organization, Pattern Models, and Music, Organised Sound 9(2), Cambridge University Press, 2004.

[15] H. Purwins, B. Blankertz, and K. Obermayer, Computing Auditory Perception, Organised Sound 5, 159-171, 2001.

[16] H. Purwins, B. Blankertz, T. Graepel, and K. Obermayer, Pitch class profiles and inter-key relations. Computing in Musicology, 15. In print.

[17] Sapient Corporation, User research and Design, http://www.sapient.com.

[18] J.C. Zoels, and S. Gabrielli, Creating Imaginable Futures: Using Design Strategy as a Foresight Tool. ACM DUX03 Conference, S.Francisco, USA, 2003.

[19] R.F. Voss and J. Clarke, 1/f Noise in Music and Speech, Nature 258:317-318, 1975.

[20] Y. Visell, The sensual move: gesture learning and sensorymotor interaction design. Int. Conf. on Multimodal Interfaces, 2006. Submitted.