Available online at www.sciencedirect.com
ScienceDirect
Mathematics and Computers in Simulation 77 (2008) 443–452
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Intelligent sensory evaluation: Concepts, implementations, and applications

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Available online 4 December 2007

Abstract

Sensory evaluation has been widely applied in different industrial fields especially for quality inspection, product design and marketing. Classically, factorial multivariate methods are the only tool for analyzing and modeling sensory data provided by experts, panelists or consumers. These methods are efficient for solving some problems but sometimes cause important information lost. In this situation, new methods based on intelligent techniques such as fuzzy logic, neural networks, data aggregation, classification, clustering have been applied for solving uncertainty and imprecision related to sensory evaluation. These new methods can be used together with the classical ones in a complementary way for obtaining relevant information from sensory data. This paper outlines the general background of sensory evaluation and the corresponding industrial interests and explicitly indicates some orientations for further development by IT researchers.

Keywords: Sensory evaluation; Fuzzy logic; Data aggregation; Classification; Clustering; Uncertainty

1. Sensory evaluation: concepts, background and industrial interests

In today's industrial companies, sensory evaluation is widely used in industry especially for quality inspection, product design and marketing. It also concerns other specialized areas such as risk evaluation, investment evaluation and safety evaluation. A classical definition of sensory evaluation is given by Stone and Sidel [48] and Dijksterhuis [13] as follows:

> Sensory evaluation is a scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of products or materials as they are perceived by the senses of sight, smell, taste, touch and hearing.

Initially, sensory evaluation or sensory analysis was developed for studying the reactions of consumers to certain characteristics of food products. These reactions are generally in the form of scores given to attributes or descriptors perceived in the food stimuli. Next, these sensory data are further analyzed using classical factorial multivariate methods such as Principal Component Analysis (PCA) [17], Generalized Canonical Analysis (GCA) [52], Generalized Procrustes Analysis (GPA) [19], in order to identify consumer's perception on new food products, predict consumer's future purchase decisions and to provide explicit indices for development and design of new products.

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doi:10.1016/j.matcom.2007.11.013

Based on the success of sensory evaluation in food industry, this research topic has been recently developed in other industrial areas for characterizing quality of products and providing new design criteria and sales arguments [18]. In these industrial areas, attention is given to organizing and structuring resources to better operate in a more and more competitive business environment. For taking advantages in business competition, industrial companies need to be more flexible, reactive and quick in production and design. Concretely, this need can be satisfied by proposing diversified products according to consumer's preference and shortening cycles of product design and product development in order to be adapted to changes of market in real time and catch new business opportunities. Integration of sensory parameters in product design can effectively help companies to reach these two aims.

Nowadays, apart from food industry, sensory evaluation is widely used in the fields of cosmetic industry, textile industry, chemical industry, packaging techniques, sportive products design, and automobile industry. In all these industrial sectors, automobile industry plays some leading role in the development of sensory techniques in product evaluation. In many big international automobile groups can be found research departments specialized in the characterization and aggregation of the reactions of customer's five senses to different parts of automobiles. The results of this "multi-sensory" study are systematically taken into account in the new design of personal cars for supporting efficient, safe and comfortable travel.

Sensory evaluation is usually carried out by one or several sensory panels. A sensory panel is a group of individuals evaluating a number of samples. In the evaluation, each individual or panelist gives a number of linguistic descriptors to the whole set of samples to be evaluated and then for each descriptor, he or she assigns a numerical or linguistic score to each sample according to his/her specialized experience and his/her classification result of these samples.

In practice, different kinds of sensory panels are used for collecting sensory data on industrial products in different backgrounds. These sensory panels can be roughly classified into two levels: (1) product design and development, and (2) consumer and marketing research.

In product design and development (B to B), sensory evaluation is done by a trained panel composed of experienced experts or consultants within the enterprise for judging the products on a number of analytical and neutral linguistic descriptors. The hedonic quality appreciation of the products is not taken into account in the evaluation. In consumer and marketing research (B to C), sensory evaluation is given by untrained consumer panels using analytical and hedonic descriptors according to their preference on the products to be evaluated.

In product design and development, technological knowledge on products is strongly integrated in sensory evaluation and characteristics of industrial product quality, called sensory profile can be systematically determined by trained expert sensory panels. In marketing exploitation, hedonic evaluation results given by consumer panels are often taken as an index for understanding consumer's behaviors, predicting their future purchasing decision and exploiting new markets. By exploiting the relationship between sensory profiles and consumer hedonic evaluation data, new industrial products can be designed to satisfy the specific needs of consumers at different levels.

In practical sensory evaluations, companies work with different panels in order to obtain relevant data according to their specific needs. According to the book of Dijksterhuis [13], these panels can be generally classified into the following categories:

- Field panels: non-trained consumers randomly selected at shopping centers are invited to answer questions in a predefined questionnaire.
- Consumer panels: selected non-trained consumers are invited to do evaluation in a laboratory under controlled conditions.
- Free choice profiling panels: each trained panelist evaluates products with his linguistic terms selected freely.
- Quantitative description analysis panels: trained panelists evaluated products with standard linguistic terms.
- Expert panels: experts specialized in a specific technology evaluate typical products and define criteria of evaluation.

From field panels to expert panels, the level of training and the engagement of specialized technology knowledge increase gradually while the personal preference on products to be evaluated and marketing elements decrease. For sensory data collected from different panels, the corresponding mathematical models and the data processing procedures are different.

In practice, setting up a suitable mathematical formulation, an efficient working procedure and a pertinent computing method for sensory evaluation is quite difficult because of uncertainty and imprecision in sensory panels and their results involving linguistic expressions, non-normalized data, data reliability, data stability, etc. Evaluation results given by