Indirect pairwise comparison method – An AHP-based procedure for sensory data collection and analysis in product development and reliability tests

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The quality of many products can only be fully measured through sensory evaluation of some of its properties. Such products abound in the food and pharmaceutical industry. There are also many industrial products that require sensory evaluation, for example, where units degrade to a threshold condition rather than failing. In these situations product quality is obtained from sensory panels.

This paper presents a methodology for selecting design or production variables to optimize or improve products where some of the quality characteristics are measured using sensory panels. The method includes procedures for collecting and analyzing sensory data. Then a model is created where the sensory characteristics are expressed as a function of the design variables. This model can then be used to identify improved design or operating conditions. We present two case studies to illustrate the methodology – a pet food application and a plastic tile application.

Samples evaluated in sensory panels usually correspond to different outcomes of an experiment, i.e., different formulations of a product, manufacturing setups, and so forth. Ideally, evaluation results should allow the analyst to relate factors varied when preparing samples to their corresponding sensory impact through mathematical models. Such models may only be determined when sensory evaluation of samples yields quantitative data, one or more measurements per sample.

Descriptive sensory analyses are particularly useful in providing quantitative descriptions of both qualitative and quantitative sensory components of samples. Different descriptive analysis methods have been suggested over the years and reported in a range of applications, as surveyed in Murray *et al*. (2001). In general, method procedures call for highly trained panelists to evaluate several sensory components of samples, one sample at a time.
In this paper we propose Indirect Pairwise Comparison (IPC) method for sensory data collection and analysis. Our method presents two features that may appeal to product development practitioners: (*i*) a consistency index objectively measures how well each panelist performs sensory evaluations; and (*ii*) reliable sensory panel data may be elicited from relatively untrained panelists.

Data analysis in our method uses analytic tools from Saaty's (1980) AHP, a methodology used in decision making for selecting the best among a set of alternatives, given some criteria. Fogliatto *et al.* (1999) and Fogliatto & Albin (2001) originally proposed the use of AHP in product development involving sensory variables, focusing on the multivariate optimization problem. The present article details the procedure for sensory data collection and analysis outlined in those works.

The method proposed uses the central idea of magnitude estimation (ME) procedures, namely, measuring the intensity of an attribute as perceived from different samples using ratios of intensities. Such application is not new in sensory evaluation, as reported by Jacobs & Moskowitz (1988). We also incorporate the use of graphic rating scales to measure responses, as suggested in Quantitative Descriptive Analysis techniques (Meilgaard *et al.*, 1999).

The key to the IPC method is to quantitatively evaluate the intensity of sensory attributes in samples by comparing them to a control sample. We present the panelist with the entire group of N samples, one of which is identified as the control. The panelist is asked to evaluate samples regarding the intensity of a given attribute, recording evaluation results on a printed scale. Intensities as perceived in the samples are marked on the scale according to their relation to the control: the center of the scale corresponds to a sample with intensity identical to the control and the extremes correspond to samples with intensities much weaker or much stronger than the control; intermediate scale points denote compromise situations. We then change the control sample and ask the panelist to perform the evaluations once again. In a complete run of the IPC procedure, each sample will be the control at its turn. In that case, after completing the data collection N printed scales will be at hand. However, incomplete runs of the procedure are also possible.

Scale marks are converted into numerical values reflecting the results of comparing each sample against the control. We create an $(N \times N)$ square matrix with rows labeled 1 to N, each corresponding to a control sample, and entries a_{ij} giving the result of comparing sample j against control sample i. Numerical results from each of the N scales are then written onto the judgment matrix, in their appropriate rows. There will be one judgment matrix per panelist.

Through algebraic manipulation we extract the following information from a judgment matrix: (*i*) a weight vector giving the intensity ranking of the samples, and (*ii*) a consistency ratio giving the performance measure for the subject. Such information may be used in a weighted regression scheme to model sensory variables, for example.

Two case studies illustrate the method proposed. In both cases we wanted to determine the best product formulation and process parameter settings. The optimization procedure requires regression models describing product characteristics, including sensory components of products. The first case deals with the development of a new formula for a well-known brand of a pet food product (dog biscuits). A 5-subject sensory panel evaluated two sensory attributes: texture and general appearance. Texture data yielded a regression model with R^2 of 0.67 when evaluations from all panelists were considered; appearance data yielded a model with R^2 of 0.97.

The second case deals with a degradation test performed on plastic tiles. A 6-subject panel evaluated degradation of samples. Degradation data yielded a regression model with R^2 of 0.95. In both cases, product optimization combined sensory attributes and quantitative responses in search of the best product.

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