Odor Assessment of Automobile Interior Components Using Ion Mobility Spectrometry

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***Abstract*—Evaluating and improving odors emitted from automobile interior parts can help automotive companies fulfill prospective customers' expectations of odor character and health impacts. Extending our previous work on machine-versus-human odor assessment for intact automobile cabin interiors, in this study we evaluated odors generated from individual interior parts using a human panel and ion mobility spectrometry (IMS). We used image processing to extract geometric features from IMS dispersion fields, and built predictive models for three odor assessment parameters (intensity, irritation, and pleasantness) by means of partial least squares regression. Using cross validation, we achieved statistically significant correlations in the range from 0.483 to 0.616 with a sample set of 48 interior automobile parts. These results support the feasibility of replacing a human panel by machine-olfaction for the assessment of odor quality of interior automobile parts.**

Keywords— automobile odors; machine olfaction; ion mobility spectrometry; odor assessment; partial least squares regression

I. Introduction

In addition to reliability and safety, odors quality has become an important factor in customers' preferences when they acquire new automobiles. Odors inside automobiles are complex mixtures of various volatile organic compounds (VOCs) that partly come from the materials of various interior parts. In order to improve customers' impressions of a manufacturer's automobile offerings, the odor (gas mixture) emitted from each part should be evaluated for its contribution to collective cabin odor. In this study we evaluated odors emanating from 10 parts from five different vehicle models provided by the Hyundai Motor Group.

Traditional machine olfaction systems are based on arrays of cross-selective sensors using gas sensing technologies, including metal oxide semiconductor (MOS), MOS field effect transistor (MOSFET), conducting polymer (CP), surface and bulk acoustic wave (SAW, BAW), fluorescence (FL), infrared (IR) absorption, and optics [1-3]. Because of the limited chemical selectivity of a single sensor, an array of gas sensors can expand the system's sensing range. Such a sensor array combined with pattern recognition methods constitutes a machine olfaction system, which is also called an electronic nose (e-nose). An e-nose can identify chemicals and predict sensory attributes of gas mixtures [4]. But the sensor array is usually selected to respond to specific gas mixtures. When the target gases are changed beyond the system's original design, the system will be inaccurate.

Ion mobility spectrometry (IMS) is an alternative technique to detect a wide variety of gases. This technique was developed for gas sensing in the early 1970s [5]. It is a portable and sophisticated chemical analyzer for detecting a wide range of organic chemicals [6]. IMS can monitor ambient air to detect target gases in real-time with a measuring resolution in parts per billion. IMS identifies analytes by their mobility according to molecules' size, mass, charge and shape, which enables measurement of a large range of analytes. Since many factors can affect the spectra, there are no commonly accepted standards for experimental conditions to reach optimal IMS performance. Finding odor-relevant information under different experimental conditions is the challenge when developing an IMS-based machine olfaction system.

In this study, we employed a Lonestar IMS by Owlstone, Inc., to examine odors generated from different automobile parts. Image processing methods were used to extract efficient odor-relevant information from acquired IMS spectra signals. Regression models based on selected features were built to predict three odor sensory parameters (intensity, irritation, and pleasantness) for the respective automobile parts. This paper is organized as follows. In Section II, the experimental setup and detailed procedures are introduced. Feature extraction methods are described in Section III, as well as regression models using partial least squares. Conclusions from the study are summarized in Section IV.

II. Experiments

A. Samples

Odor can emanate from a variety of component parts comprising an automobile's interior cabin. Table I lists our selection of 10 types of parts (labeled from "a" to "j") from five different automobile models (labeled from "A" to "E"). The selected parts were: floor carpet, floor mat, headliner, instrument panel, rear package tray, cloth bolster for seat cover, cloth insert for seat cover, leather bolster for seat cover, leather insert for seat cover, and seat foam. Two of the models had no rear package tray, so a total of 48 samples were tested (each sample's identifying number is listed in Table I).

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