Symbolically Describing the Sensory Perceptions from an Artificial Nose

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For the past two decades, electronic noses are being developed to serve a wide variety of industrial applications in addition to providing many insights into biological systems. A large part of the development into olfaction has been focussed on the sensor technology and development of sensor systems capable of measuring chemical gases [3]. To complete the model however, consideration needs also be given to the interpretation of the sensor data and the communication of these interpretations to an end user. This is especially important in applications where human and sensor systems need to co-operate in assessing the quality or the nature of an odour. It is also useful in the case where the human user is not an expert in artificial sensor systems for example in applications such as quality control in the food industry, detection of hazardous gases and evaluation of odour characteristics. In order for electronic noses to be useful in many applications, there is a need to correlate the human conception of odours to the electronic one. One way to satisfy this need is to ground a common language to the perceptions of both sensor systems.

Determining how to appropriately label olfactory signals is a challenging problem. This challenge is due mostly by the fact that for humans there is no direct correlation between the name given to odours and the chemical composition of an odour. Common odours are often described by their quality or the experience felt when sensing particular smells and are rarely identified in terms of their chemical nomenclature or fixed standards [1]. Therefore facing the possibility that the progressing sensor technology in electronic noses would in many ways be able to outperform humans in the detection of odours, it is highly advantageous for such a system to be able to convey its own perceptions on a symbolic level. The main challenge, however, is to correctly represent the sensor data with a set of predefined labels. The labels then serve as a common lexicon between the human and the electronic device. Additionally, the system would need to be able to manipulate the symbols to accord with its sensor perceptions. Therefore, the system maintains the freedom to evaluate the appropriateness of the given symbols with respect to the sensory analysis space, thus possessing the capability to communicate or describe its own perception of odours using a common lexicon.

To cluster the data from the electronic nose, we implement a robust competitive clustering algorithm (RCA) created by Frigui et al. [2]. The technique is a hybrid of hierarchical and partitional clustering. The method uses the hierarchical technique of ”agglomerating” data points while maintaining knowledge of the global shape. The main advantage is that fuzzy memberships allow for overlapping clusters while the robust statistics compensate for the possibility of outliers. See [2] for more detail on the algorithm. The following is a list of possible scenarios which occur from clustering and how the cluster labelling is managed:

1. Number of Clusters exactly match the number of different labels - In this case the perceptions of the human match those of the nose and cluster C_1 is assigned the label of $OdourA$, $C_2 = OdourB$ etc.

2. Number of clusters are less than the number of different labels - This represents the case where the nose has difficulty discriminating odours in which case the label of cluster may be compounded to include the names of the two or more labels such that $C_1 = OdourA \wedge OdourB$.

3. There exist more clusters than the available labels - The electronic nose is more selective than the human. Since we do not want clusters with the same labels we choose arbitrary labels to separate the clusters with similar labels such that $C_1 = OdourA_1$ and $C_2 = OdourA_2$.

Once labels are determined for the clusters, we implement a set of rules which behave as a syntactical guide to yielding a full description of an odour. The clustering process is a fuzzy clustering such that points on the same space and particularly in the same cluster are related to a cluster by a degree of membership. This fact, allows new data to be described in relation of the labelled clusters. To do so, fuzzy if-then rules are used to describe linguistically the value of the membership degrees of the unlabelled points to the labelled clusters. The net result is a compound description which comprises of one or more labels and each label has a prefix reflecting the degree of membership. The key to linguistically describing the membership values is to reflect a level of confidence using symbolic terms. This means that if the membership to a cluster is high we attach a prefix to the symbolic label of the odour to reflect this fact.

The primary objective of this work is to be able to create an artificial system capable of using familiar terms while retaining its own independent mapping of the data. Furthermore in the case where the perceptions between human and electronic nose differ, we want the system to be able to highlight those differences in a language which humans understand. We use a combination of the knowledge of the sensor systems in conjunction with simple symbol grounding and concept learning techniques [4]. This allows the system to be capable of describing unidentified points on its feature map through the manipulation of known symbolic terms. Future work will concentrate on more rigorous testing and eventual expanding of the techniques to deal with more diverse situations such as overlapping clusters. A second area of research will be focussed on applying the method to other electronic perceptual devices such as electronic tongues whose operating principles are very similar to the electronic nose.

Please visit www.aass.oru.se/ ˜ali/pub.html for more publications from the authors on the research area.

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