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Monitoring Household Garbage Odors in Urban Areas Through Distribution Maps

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***Abstract*—This paper presents an experimental study of the suitability of a mobile e-nose (carried on a bike) for the monitoring of unpleasant and potentially harmful odors in urban areas, likely coming from residential waste containers. The objective is to obtain a spatial and temporal representation of such odors by means of a gas distribution map, from which valuable information such as the location, or the time-intervals of maximum strength of the nuisance odors can be inferred. As a case of study, the results of a monitoring campaign carried out in a town in southern Spain are presented. The campaign comprises nine measurement runs distributed along three consecutive days, with a total path of more than 90Km. Upon the results, it is concluded the feasibility and potential of the approach, but also the need for a precise sensor characterization and for gas classification.**

I. Introduction

The increased demand of the population for a clean and pleasant environment has encouraged the control of odor emissions and toxic air pollutants in urban areas. Even in developed cities with warm climatic conditions, many are still the complaints about unpleasant odors [1]. Among those complaints, a large number are related to the waste management system: household garbage is periodically deposited in waste containers distributed along the city for its posterior collection and treatment by the cleaning services. Favored by certain weather conditions like rainfall and high temperatures, within a few hours the organic matter may begin to decompose and release different kinds of chemical gases characterized by an unpleasant odor. According to Eitzer [2], it is during the early stages of the composting process of municipal solid waste when most of these volatile compounds are emitted. This entails that the decomposition of the household garbage starts in many occasions at the waste containers (specially at those exposed directly to sun light), generating malodorous emissions and producing a negative impact on the population.

The effect of ambient aromas in humans' behavior is still not well understood, but studies have proven changes in the creativity, mood or even in the perceived health status [3]. Thus, not only for a commercial perspective (focusing mainly on tourism), but to improve residents health status in general, the emission of nuisance and unpleasant odors should be monitored for its appropriate control.

This work reports on a experimental evaluation of the use of a mobile e-nose for spatial and temporal monitoring of unpleasant odors in urban areas, likely coming from the waste deposited in garbage containers. The objective is to evaluate whether information such as the locations, intensities along the day, or the districts affected by such emissions, can be inferred from the measurements of the e-nose.

II. The Problematic Behind Monitoring Waste Emissions

As opposed to most pollution monitoring applications where the target pollutants are well determined [4], [5], monitoring waste related emissions presents a number of particularities that make the problem quite a challenge.

The emissions generated in the decomposition process of biological matter are heavily influenced by the type of wastes, the time elapsed since they were deposited or the climatic conditions (temperature and humidity are important variables in the decomposition process). Typically, they are constituted by chemicals derived from nitrogen, sulphur and a wide group of compounds denominated volatile organic compounds (VOCs) [2]. Specifically, VOCs refer to substances characterized by a high vapor pressure at ordinary room temperature and a low water solubility [6]. Once in the atmosphere, VOCs participate in photochemical reactions producing oxidants [7], such as ozone (O_3), peroxyacetyle nitrate (PAN) and hydrogen peroxide (H_2O_2), which excessive concentration has been shown to have toxic effects on both plants and human health [8], [9].

Given the wide spectrum of VOCs associated to waste emissions, the focus shifts then to the election of gas sensors able to detect them. Among the different available technologies, in this study we select metal oxide (MOX) gas sensors because they are small and lightweight (desired properties for obtaining portable devices), are low-cost, and most importantly, they show a high sensitivity to the target gases [10]. The latter is a fundamental characteristic to our study since the expected concentrations to be measured from a single waste container are much lower than those produced in a landfill or a composting facility. As disadvantages, MOX technology exhibits a slow response [11], [12], and a considerably lack of selectivity. However, the latter turns in our case to be a desirable property since as discussed above, the compounds emitted from waste decomposition are diverse and numerous, so increasing selectivity will reduce the chances of detecting emitted VOCs. A side effect of this property is the possible detection of other sources of volatiles apart from waste (sewers, smoke, etc.). To deal with it, pattern analysis performed over the response of an array of MOX sensor with partially overlapping selectivity have proven successful [13].

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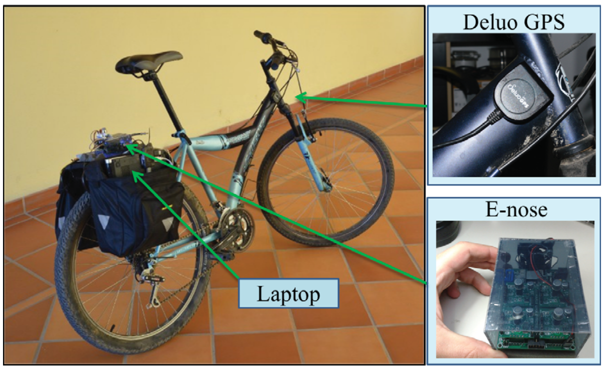

Fig. 1. The data collection system consists of a bicycle carrying a laptop, a GPS and the e-nose comprising 7 MOX sensors.

Nevertheless, this analysis has not been considered in this work, but is left for future work.

Thus, evidences about the compounds emitted by waste containers and the availability of technologies able to detect them, suggest that monitoring waste-related odors in urban areas through mobile low-cost e-noses is feasible. The experiments described next are aimed to confirm such evidences, generating georeferenced gas distribution maps from which we can bring out limitations and problems of the proposed system, and also learn about the next steps to follow.

III. Data Collection System

Traditionally, the measurement of gas concentration in urban areas has been handled by deploying networks of static sensor nodes. Although this approach has proven to be effective for applications like pollution monitoring, it also presents some drawbacks and limitations like the poor spacial resolution, the lack of flexibility and the elevated cost of deployment and maintenance. Thus, we believe that a data collection system based on a mobile sensor represents a more effective solution. Concretely, for this experimental study we propose to use an e-nose transported by a bicycle.

Figure 1 shows a picture of the employed bicycle and the onboard equipment. The bicycle (a conventional mountain bike) has been equipped with an e-nose based on an array of 7 MOX gas sensors, an external GPS (DeluoGPS) for extra localization accuracy, and a laptop to record the data and provide synchronization. Samples from all gas sensors together with the GPS location are taken at 1Hz and transmitted to the computer with time-stamps, which records such information in a log file. It is important to notice that both the e-nose and the external GPS don't have high power requirements, allowing to be powered with the laptop battery via the USBs ports. Flanges and foam are used to fasten and protect the equipment from shocks during the measurement rides.

It is worth mentioning that measurements taken in motion from a bike may be not as precise as those taken still or on foot, since the time between expositions (e.g. different containers) is reduced, and consequently less time is available for the sensor to recover. Similarly, shorter expositions to the volatiles, yield measurement of concentrations bellow the "real value", especially for slow-response sensors as in the case of MOX. This is clearly noticeable when comparing the sensor

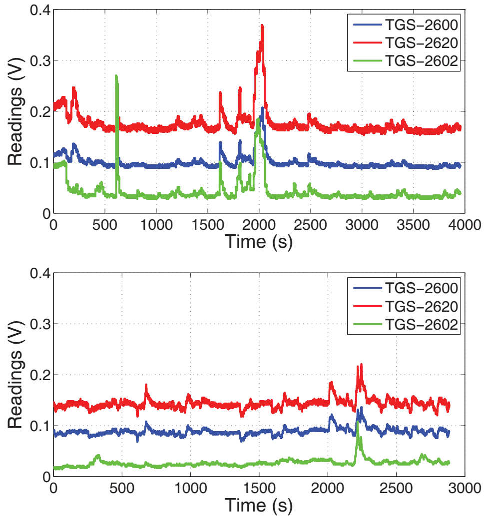

Fig. 2. Readings of three different MOX gas sensors obtained while measuring waste volatile compounds taken on foot(top), and by bicycle(bottom).

readings gathered while biking with those obtained in a more static setup, for example on foot (see Figure 2). However, by considering a re-scaling of the measurements obtained while biking, these differences can be palliated, and consequently, an adequate detection of the target VOCs is possible as shown in the experiments.

Finally, related to the election of the MOX sensors comprising the e-nose (see Table I), they have been chosen having in mind the wide spectrum of volatile compounds that may be emitted by waste (see Section II). Thus, sensors with different selectivities have been chosen to enhance the detection of different VOCs. This, as previously mentioned, introduces the problem of detecting other sources apart from waste containers.

IV. A Case Study

An study of waste odors was carried out in Coin ($36°49'N$, $4°45'W$), a town in the province of Málaga, southern Spain. An approximately 10Km route was defined along the town center, passing by several waste and recycling containers as shown in Figure 3. The data collection process consisted of three runs per day (9:00h, 18:00h and 21:00h) during three consecutive days (18th to 20th July 2014), with a total of 90Km and more than 30.000 observations collected. Figure 4 shows some pictures where the bicycle and the e-nose can be appreciated.

TABLE I. Gas sensors used for the monitoring of waste produced VOCs.

Manufacturer	Model	Target gases
Figaro Inc.	TGS-2620	organic solvents
Figaro Inc.	TGS-2602a	organic compounds
Figaro Inc.	TGS-2602b	organic compounds
Figaro Inc.	TGS-2600	air contaminants
Hanwei electronics	MQ2	alcohols, smoke, CO
Hanwei electronics	MQ9	CO, coal gas
Shenzen Dovelet	TP-401A	air contaminants

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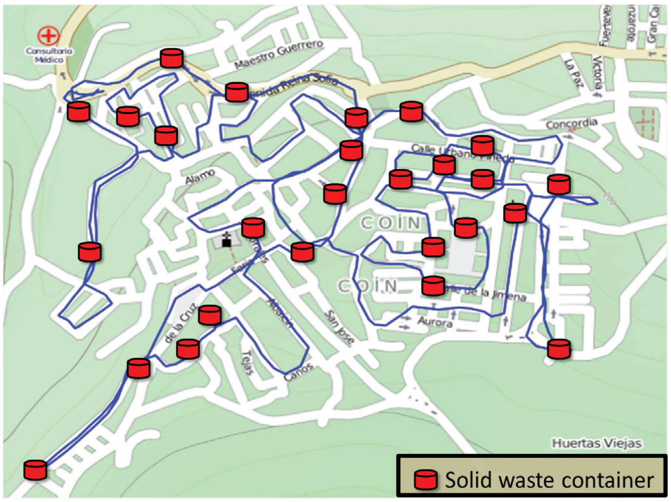

Fig. 3. Route followed during the data collection process (blue line), and detailed location of the waste containers encountered along it (red cylinders).

A. *Creating Gas Distribution Maps*

Figure 5 shows the gas distribution maps obtained for the different runs of the monitoring campaign. Such maps have been generated using the kernelDM+V method [14], which, in a nutshell, consists of the convolution of the sensor readings with a Gaussian kernel, providing the necessary spatial-temporal aggregation for a clear visualization of the results.

In view of space constraints, only the mean of all MOX sensors (after normalization) is plotted for illustrative and validation purposes. A deeper study of the suitability of the different sensors for the monitoring of waste related emissions, as well as the consideration of different methods for merging the spatial and temporal data collected, is left for future work.

B. *Analysis of the Results*

From the spatial characteristics of the maps shown in Figure 5, it can be appreciated how different sources of VOCs are detected and localized during the different runs of the monitoring campaign. Most of these "odorous spots" can be related to the presence of close containers, taking into account that the peak concentration of a gas emission is usually displaced from the source location due to the continuous airflows present in real environments. Another aspect that suggests waste containers as the sources of the detected emissions is the fact that the highest concentrations are usually found in the most populated areas of the town (region on the center-right of the map), where more garbage is produced.

Yet, other spots with relatively high concentration are detected with no direct relation to waste containers. Examples can be found in the spot located around cells (50,40) in the first inspection run (18th July, 9:00), or in the spot located at cells(65,45) during various inspections. This, as mentioned in Section II is due to our decision of employing a a set of gas sensors with a wide spectrum of target gases. Thus, although in this initial evaluation it is not possible to state if these spots are caused by some other type of chemical source (e.g. sewers), we can certainly conclude that e-nose devices are suitable for

Fig. 4. Pictures taken during the data collection carried out in Coin (Málaga) for the monitoring of waste related odors. The bike was equipped with an e-nose comprising an array of 7 MOX gas senors and a GPS for proper localization of the measurements.

the detection and localization of VOCs sources in urban areas. However, further analysis of the problem is required in order to correctly differentiate among waste containers and other possible sources of VOCs.

Referring to the temporal variability of the maps, in general, higher concentrations were measured for the late hours of the day. This, as expected, is linked to the fact that most people take out their garbage in the afternoon, and to the increase of average temperature in the middle hours of the day, which favors the decomposing process, increasing the VOCs emission rate.

V. Future Work

What it is presented in this paper is just an initial study towards exploiting mobile e-noses to monitor odors in a urban areas. The results have shown to be promising and pointed out a number of directions for future work. One of them is a deeper study of the compounds emitted by waste to investigate whether machine learning techniques could be applied to differentiate among types of waste and between other possible odorous sources present in urban areas such as sewers. Also, further processing of the data such as compensation for the speed while measuring, or the slow recovery of MOX will be considered.

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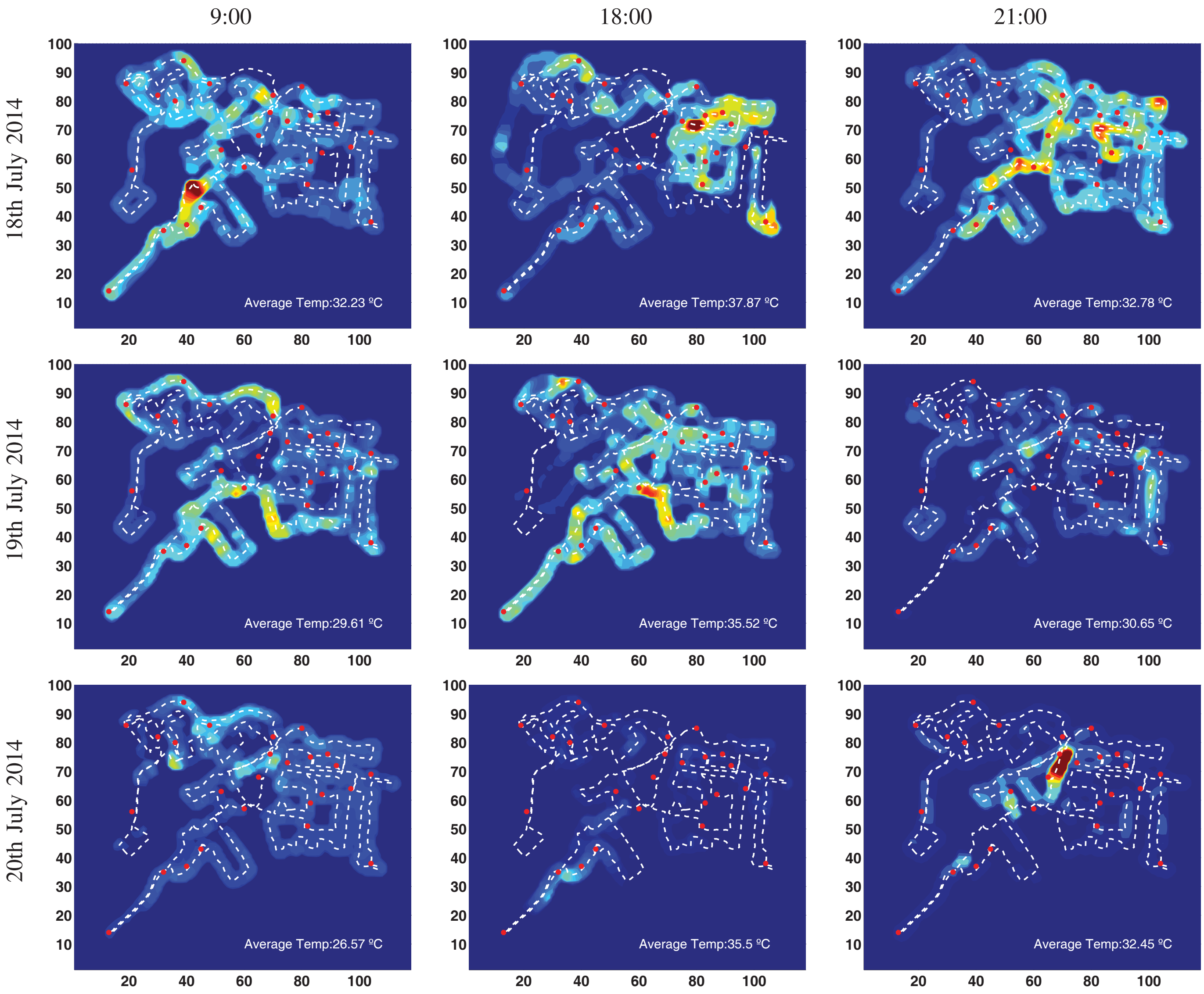

Fig. 5. Maps of the estimated VOCs distribution for the different runs of the monitoring campaign. Axis are expressed in cells, white dash line depicts the path followed in the inspection, while the location of waste containers is marked as red circles.

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