Remotely Controlled Terrestrial Vehicle Integrated Sensory System for Environmental Monitoring

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Abstract. In this paper we show the developing and the applications of a remotely controlled terrestrial vehicle (or Unmanned Ground Vehicles—UGV) provided with an integrated sensory system for environmental monitoring. The developed system is aimed to monitor some of the key air pollutants and harmful compounds, usable in contaminated sites at high risk to human health. The system is a 4WD radio-controlled vehicle, with small dimensions and low weight, complemented by a sensory system based on hybrid sensors technology (e.g. optic, electrochemical, gravimetric, etc…). These features allow this system to be easily used when inspection missions are required, before or after any environmental disaster. It is able to measure, in few minutes, the atmospheric particulate matter (PM1, PM2.5, PM10), CO_2 and CO, H_2S, SO_2, NO_2 in the range between 15 and 5000 ppb. Moreover, it is equipped with a telemetry system for the remote-controlled navigation, including a high-resolution camera, a GPS antenna, an anemometer and proximity sensors. The core of the device is a microprocessor board able to assist the navigation, acquiring values from sensors, transfer/record data and control tens input/outputs up to a distance of 1 km. In this work we report some information regarding the integration, the calibration and the data related to the monitoring of a waste landfill in the closing phase, during the construction of the extractor for generated biogas.

Keywords: UGV · Monitoring system · Gas sensors

1 Introduction

Unmanned Ground (UGV), Air (UAV), Surface (USV) and Underwater (UUV) vehicles are useful in a wide field of civil applications such as: environmental monitoring, agricultural surveys, emergency and disaster relief [1–5]. There are companies that sell UGVs that are able to detect leaks of oil and gas in the infrastructure, ensuring human safety. Other companies that offer UGVs able to enter into pipe systems to monitor toxic waste and chemical or radioactive material. In research field, there are USVs capable of sail the oceans and to report to scientific communities the measured data, anywhere in the world. Advances in the electronics integration and software are

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steadily increasing bringing the autonomous UGV navigation system towards low costs with excellent level of reliability. At the same time, the growing demand of data related to environmental pollution by policy makers, citizens and the scientific community have stimulated the development of UGV with on-board environmental monitoring systems.

We therefore propose a UGV system aimed to monitor some of the key air pollutants and harmful compounds, usable in contaminated sites at high risk to human health. In this paper we show the details of development and an application of a remotely controlled terrestrial vehicle with sensory system integrated for environmental monitoring. In particular, we report the results obtained from a measurement campaign that consisted in the monitoring of the diffused emissions in a waste landfill area.

2 Experimental and Results

Proposed system consisted a 4WD (all-wheel drive) radio-controlled vehicle, with small dimensions and low weight, complemented by a sensory system based on hybrid sensors technology [6, 7]. Such a sensory system assembled within a terrestrial vehicle, is able to measure: atmospheric particulate matter, CO_2, CO, H_2S, SO_2 and NO_2. Starting from a commercial radio-controlled model (by Traxxas) we have designed and developed a complete system that includes: vehicle, air sampling system for gases and particles, a sealed measuring sensors chamber, a camera with wide angle lens and an electronic controlling board (electronic) as depicted in the sketch (Fig. 1). The air sampling system commutates between two distinct phase. During the measure, it delivers the air (to be analyzed) to the sensors chamber. In the cleaning phase, it creates the zero air, using a filter cartridge (Filter) and then delivers it to the sensor chamber.

An integrated optical particles counter (OPC-N2 by Alphasense Ltd) was used to measure the amount of PM in the sampled air. The data generated by the OPC are divided into three main classes, PM1, PM2.5 and PM10. The OPC sends the data to the electronics that gets the data every 2 s. The CO_2 concentration (0-5000 ppm) was measured by a NDIR sensor (IRC-A1 by Alphasense Ltd). Electrochemical sensors (by Alphasense Ltd) were used to measure the concentrations of CO, H_2S, SO_2 and NO_2 in the range between 15 and 5000 ppb. The electronic board was equipped with a telemetry system for the remote-controlled navigation, which includes: (i) a high-resolution camera; (ii) a GPS antenna; (iii) an anemometer and (iv) proximity sensors. The core of the electronics was a microprocessor board able to assist the navigation, acquire values from sensors, transfer/record data and to control tens of input/outputs up to a distance of 1 km.

After the integration phase the system was tested in various scenarios, with different soils structure and composition, to check the UGV navigation performances (see Fig. 2).

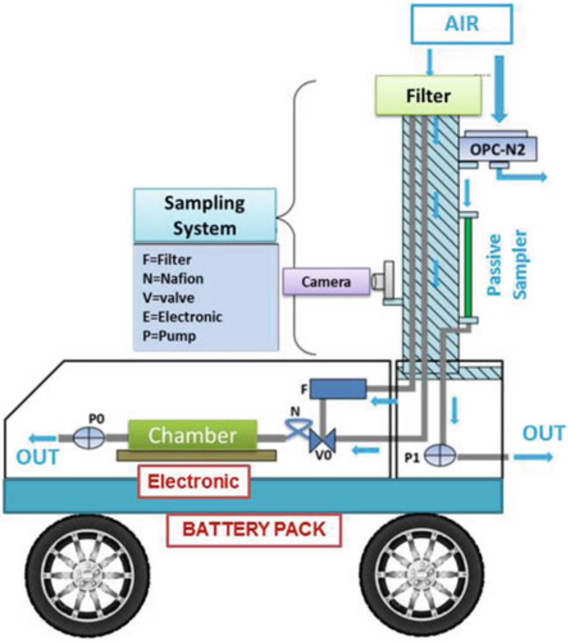

Fig. 1 Sketch of developed system

Fig. 2 Pictures of developed system during the campaign in landfill (*on the right*). The overall dimensions are 70 × 50 × 30 cm and 4 kg of weight + 2 kg of maximum payload

Before assembling, we checked and calibrated the sensors with accurate, precise and qualitatively controlled analytical instruments commonly used in our lab to measure and quantify the analyte concentrations in air. In Fig. 3 some example of dynamic sensor responses are shown, in particular in Fig. 3c the sensor responses obtained when the UGV navigated near to a traffic zone are reported.

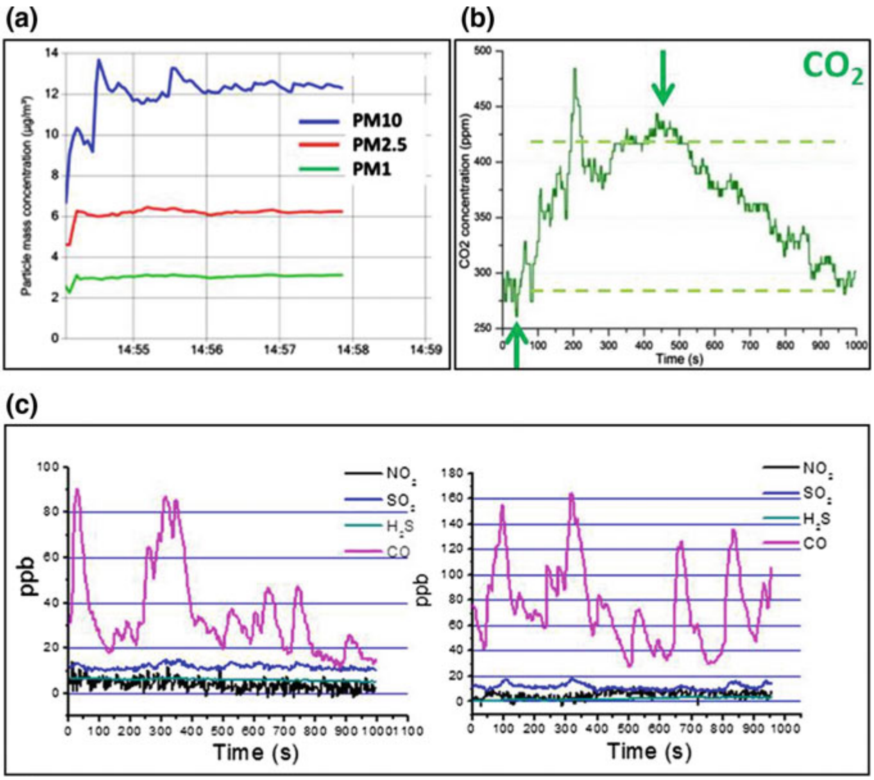

Fig. 3 Transient measurements of PM (**a**), CO_2 (**b**) and other gases during the test campaigns (**c**). In case (**c**) the system has monitored the air surrounding a traffic zone

In order to validate in a real scenario our monitoring system, we have performed several measurements in a waste landfill (about 60,000 m^2) where was in progress the developing of a biogas system. The developed UGV has monitored the gases and particles concentrations in six points of interest closed to the extraction pipes (P0,…, P5). In Fig. 4 we report the values of two gases amounts (CO_2, H_2S) recorded during the campaign. P0 an P5 were outside the landfill site about 200 m from the boundary. P1 and P3 were two points located in a part of landfill (Closed) where the extraction pipes were connected to the biogas system. P2 and P4 were located in a portion of landfill "Open" where the biogas system was to be completed. The results highlight that in the "Open" area the CO_2, H_2S concentrations were more higher than those in the "Closed" area. This result has confirmed the state of progress of the biogas system.

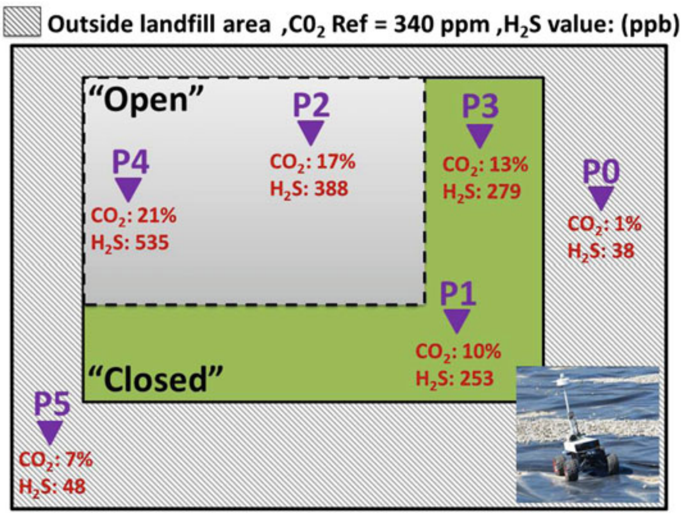

Fig. 4 Results of CO_2 and H_2S mean values for six points of interest (P0,…, P5), measured during the campaign in landfill are reported. The "Open" area means a part of landfill to be completed, vice versa the "Closed" means a completed part

3 Conclusions

We have developed and tested in a real scenario, a remotely controlled terrestrial vehicle (or Unmanned Ground Vehicles—UGV) integrated with a sensory system for environmental monitoring. The system was able to monitor atmospheric particulate matter (PM1, PM2.5, PM10), CO_2, H_2S, SO_2 and NO_2. We have validated the functioning of our system during a measurement campaign performed in a waste landfill where a biogas system was under construction. The results highlight that in the "Open" area (where the biogas system was to be completed) the CO_2, H_2S concentrations were more higher than that in the "closed" area (where the extraction pipes were connected to the biogas system). This result have confirmed the state of progress of the biogas system.

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