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Reflectance-based detection for long term environmental monitoring

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Abstract

Here, the potential of colorimetric sensors utilizing porphyrin indicators for long term environmental monitoring is demonstrated. Prototype devices based on commercial color sensing chips (six per device) were combined with in-house developed algorithms for data analysis. The devices are intended to provide real-time sensing of threats. An initial outdoor data set was collected using prototype devices with occasional spiked exposure to targets. This data was supported by similar data collected in a controlled indoor environment. Weaknesses in the noted performance of the devices during these experiments were addressed through altering device parameters, algorithm parameters, and array element composition. Additional outdoor data sets totaling 1,616 h and indoor data sets totaling 728 h were collected in support of assessing these changes to the system configuration. The optimized system provided receiver operating characteristics (ROC) of specificity 0.97 and sensitivity 1.0.

Keyword: Environmental science

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1. Introduction

The development of sensor platforms for environmental monitoring or surveillance is an ongoing area of interest. With the increased availability of connectivity technologies (cellular/WiFi) and continuing advances in supporting hardware and software, generation of consensus decisions based on distributed sensors has become more feasible [1, 2, 3, 4]. It remains true that platform development is faced with serious design constraints on power and size as well as sensor specificity and sensitivity. An additional challenge stems from the envisioned applications in which different types of information may be important. For instance, the design criteria for detailed monitoring of concentrations for a single gas target are very different from the requirements for broad spectrum monitoring of many gases at threshold levels. While sensors developed for the single gas task could be applied to the second task, there will likely be a cost imposed by capabilities that are not required, and additional complexity would be expected in coordinating many individual sensors applicable to the range of targets of interest in the second application.

Sensor methodologies are being explored to achieve a broader range of applications: remote sensing, arrays of indicators (artificial nose/tongue), and, more recently, multivariable sensor approaches [5, 6, 7, 8, 9, 10, 11]. Potyrailo [10] provides a comprehensive review of several sensor technologies and compares several sensing approaches. Standoff detection presents a compromise with a few units can covering an area of interest; however, the cost and operational requirements of an individual unit remain high [12]. The approaches also remain limited to line of sight and continue to suffer from background interference. Significant effort has been invested in the development array based sensing approaches, including various chemical sensing modes and methods to maximize the information obtained from arrays [5, 6, 7, 13]. Implementations include both electrochemical and optical approaches [5, 6, 12, 14, 15]. Optical methods range from image capture with post processing to simple color intensity measurements [6, 7, 16, 17, 18, 19]. The indicators for these sensors often use semiselective interactions to allow for long term and broad spectrum application, resulting in challenges for discrimination of targets. Various approaches have been explored as a means of addressing the cost, power, and effectiveness of the final device. Multivariable sensors represent a more recent area of research that attempts to overcome specificity issues inherent in array approaches through interrogation of an indicator element in several ways. This is a relatively new approach; the technologies tend to be less mature than the available array and standoff approaches [10].

Our focus has been on development of sensors for threshold monitoring of multiple targets [9, 13, 20]. The ongoing effort has prompted significant exploration of

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