Quality of Digital Images as Means of Ambient Fine PM Assessment

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Continuous monitoring of airborne fine particulate matter (PM) is fundamental for exposure assessment and management of environmental and public health risks. Traditionally, local continuous sampling is conducted only by sparsely distributed air quality monitoring stations (AQMS) to provide the mass fraction of particles < 2.5 µm ($PM_{2.5}$). This research aims at establishing a low-cost and flexible remote sensing methodology, based on generic digital cameras, that exploits image quality measures in order to estimate fine PM loadings in the open path between the camera sensor and the imaged scene. Differing from traditional aerosol remote sensing, the proposed method is based on indirect effects of light scattering by particles and aims to monitor horizontal near-ground atmosphere layers, thus seeking to better resolve spatial variations in ambient PM concentrations.
The effect of PM levels on image quality was examined for more than 20K images that were acquired by Canon SLR digital cameras at a rate of 5 min during daylight hours in three long-term campaigns as shown in Table 1below.

Table 1. Experiments Details

Experiment	**Period**	**Number of Daylight Images***
Haifa Bay, Israel **	July 2012 – April 2013	19,001
Brisbane I, Queensland, Australia ***	July 2015	2,190
Brisbane II, Queensland, Australia ***	August 2015	930

* Between half hour after sunrise to half hour before sunset.
** Canon EOS Rebel T2i
*** Canon EOS Kiss X6i

Image metrics including color content, hue, saturation, entropy metrics, and perceptual blur (Crété-Roffet *et al*, 2007) were calculated for every image. These metrics were analyzed with respect to simultaneously measured PM levels and meteorological conditions obtained by AQMSs along or close to the lines of sight.

Since image metrics of Haifa Bay experiment yielded low correlations to the simultaneously measured $PM_{2.5}$ levels ($R^2 \leq 0.4$), we further considered influences of illumination and meteorology conditions on image metrics. To this end, the effect of possible modifying variables such as the solar illumination angle and the ambient relative humidity, were studied.

After stratifying the Haifa Bay dataset by different modifiers, two of the image metrics produced promising results: perceptual blur metric and cyan content in the image. Multiple linear regression (MLR) models over the stratified data with those image metrics, yielded much higher determination coefficients. For example, MLR over data stratified by illumination angles to 10 quantiles produced $0.445 \leq R^2_{adj} \leq 0.656$. Additional stratifying of the dataset by the different months improved the MLR adjusting up to $R^2_{adj} = 0.967$ in certain strata.

An ongoing analysis of the Brisbane dataset indicated model dependency on setup parameters, namely, acquisition geometry and scene composition and PM composition.

A comprehensive analysis is ongoing, including additional datasets from Haifa, with different scene and acquisition frequency, in order to improve PM estimation based on image quality metrics.

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Crété-Roffet, F., Dolmiere, T., Ladret, P., & Nicolas, M. (2007). *The Blur Effect: Perception and Estimation with a New No-Reference Perceptual Blur Metric*, SPIE Electronic Imaging Symposium Conf. Human Vision and Electronic Imaging.