Demo: Handheld Particulate Matter Measurements with COTS Sensors

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1 Introduction

Current mobile phone models are equipped with a variety of sensors and ever increasing processing power. The internal sensors have been employed for various applications, ranging from classical geo-location systems over activity recognition using the native 3D accelerometer to augmented reality. However, there are application areas which require sensors that today can not yet be found in mobile phones, e.g. due to cost or size restrictions. This is especially true for scenarios involving air quality information such as the concentration of potentially harmful gases – like carbon monoxide (CO), dioxide (CO_2) or ozone (O_3) – or the level of particulate matter (PM). The importance of such applications grows with society's concern about how these pollutants affect a person's health or the environment. In the past decades, an increasing number of studies investigated the effects of particulate matter on people's health. The results are that fine dust can be a serious hazard, contributing to respiratory and cardiovascular diseases. This is why regulations aiming at the reduction of man-made particulate matter have been increasingly set by authorities around the world.

This demonstration shows the TECO Envboard, an environmental sensing platform for research and development purposes that carries a wide range of commercial off-the-shelf (COTS) sensors, many of which are today not yet built into mobile phones. The Envboard is currently used to investigate the feasibility of particulate matter measurements using a cheap, commodity dust sensor: the *Sharp GP2Y1010*.

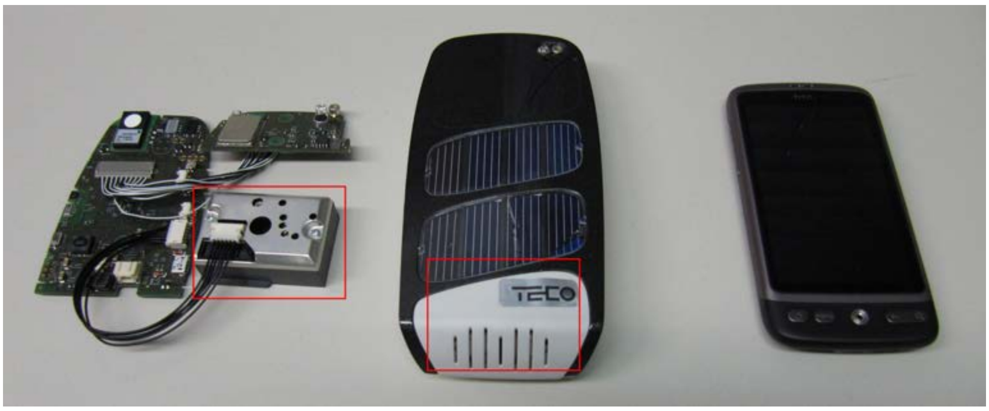

Fig. 1: TECO Envboard: PCBs and Sharp dust sensor (left) and in housing (middle).

2 Related Work

Research specifically addressing mobile measurement of particulate matter is still sparse. In the UCLA project *peir* (*personal environmental impact report*) [7], a variety of data that shows one's impact on the environment and vice versa is logged. This includes smog exposure ($PM_{2.5}$ particulate exposure). However, it is not measured but calculated based on parameters such as the closeness to known hazardous conditions or sites (e.g. freeways). Both the projects *inAir* [5] and *Common Sense* [2] measure air quality parameters using specifically developed handheld devices. However, neither of these has a dust sensor incorporated. In [4], a distributed network of dust sensor nodes was used to monitor dust in urban and industrial environments, but the authors' focus were network aspects and not particulate matter measurements. The work at hand demonstrates a platform that will be used to investigate the feasibility of meaningful PM measurements using an incorporated COTS dust sensor.

3 Applications

Mobile measurement of fine dust potentially enables more fine-grained information than stationary equipment, both spatially and temporal. Standard gravimetric measurement equipment to determine the particulate matter concentration is large and expensive and thus often sparsely deployed. Mobile measurement also enables applications as e.g. the identification of hazardous areas and pollution hot spots.

Such information could be mapped using *Participatory Urban Sensing* approaches, much like it has been done in the past to create noise pollution maps of urban areas [8],[6]. Using the Envboard as a research platform and data supply for mobile or stationary measurements (see Figure 2), methods can be investigated to improve on the sensors accuracy as well as sparse sampling algorithms. The improved spacial and temporal resolution could compensate for the potentially lower accuracy that is to be expected when using simple devices instead of expensive stationary equipment.

Since the power of negative health effects varies from person to person [1], people at risk – or their employers – may choose to monitor their personal exposure. In such scenarios, the Envboard can be used as a *Personal/Life Log*, allowing accurate and timely information on occupational exposure (e.g. in woodworking shops). Apart from research focusing on particulate matter sensing, the Envboard could serve as research platform for *Activity/Situation Recognition*. Its variety of sensors (see below) can potentially help to capture more aspects of a situation or activity. This could result in a finer distinction between classes or the ability to detect novel ones.

Fig. 2: Usage scenarios: carried on pocket, backpack or bicycle or stationary.

4 The TECO Envboard

As shown, the Envboard features different modes of operation, either taking measurements in a stand-alone fashion or connected via bluetooth to a host as an Android™ phone. Alternatively, the information can be transmitted through the Envboard's serial USB interface. The API allows for configuration of the sampling intervals, direct querying of sensors or the adjustment of calibration data. The measurements are either transmitted or stored on the integrated microSD card for later readout. The Envboard carries a plethora of COTS sensors, detecting phenomena from temperature over acceleration and noise to gas concentrations and particulate matter:

	sensor	**phenomenon**
digital	SHT-21	temperature
		humidity
	MPL115A	atmospheric pressure
	iAQ-Engine	VOC (indirect: CO_2)
	ADXL345	3D acceleration
analog	WM-61A	noise level (dBA)
	GP2Y1010	particulate matter
	TEPT5700b	ambient light
	AlGaN-TO18	UV light
	MICS 2614	O_3
	MICS 4514	CO
		NO_x
optional[1]	HMC5883	3D gyroscope
	ITG-3200	3D magnetometer
	MVS0608.02	motion/microvibration
	TGS4161	CO_2
	GPS module	global postion

The key component with respect to this demonstration is the GP2Y1010 dust sensor, whose suitability for mobile particulate matter measurement we are currently investigating. There were not a lot of small sensors to choose from (see Figure 3). This model was added to the Envboard's design because it fitted all requirements and constraints best: it is comparatively cheap, not too power-hungry as well as small enough to be incorporated into a handheld device. In addition to that, it had the best availability.

(a) **(b)** **(c)**

Fig. 3: Particulate matter sensors: *AES-1* **(a)**, *DSM501A* **(b)**, and *GP2Y1010* **(c)**.

[1] Footprints/connectors are in place, just were not populated in the demonstrated revision because the research focus being on particulate matter sensing.

5 Conclusion and Outlook

This paper and the accompanying demonstration present a mobile environmental measurement platform that can potentially be used for particulate matter measurements – the TECO Envboard. Preliminary results indicate that the measurements of the rather simple sharp sensor correspond with the actual particulate load which we measured using a gauged reference device, the *DustTrak DRX Aerosol Monitor* from TSI (Figure 4). The DustTrak can detect particulate matter in a range from $1\frac{\mu g}{m^3}$

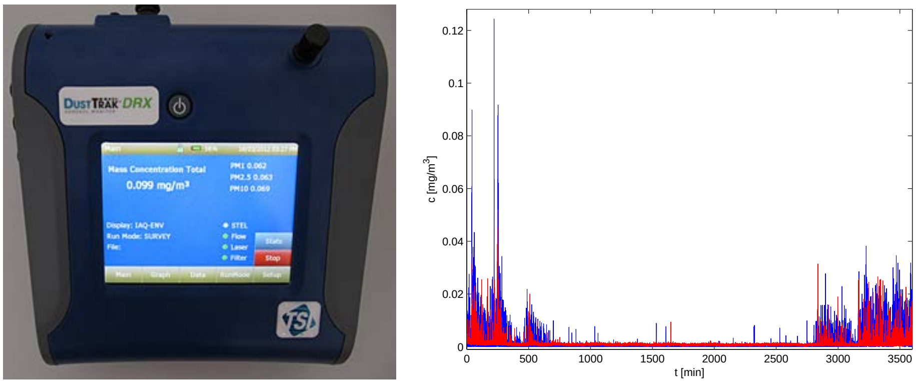

Fig. 4: Left: the TSI 8533 DustTrak DRX reference aerosol monitor. Right: data from one of the dust sensors (red curve) and the DustTrak (blue curve) in $\frac{mg}{m^3}$.

to $150\frac{mg}{m^3}$. We are currently researching in how far the noise of the sensor and the error to the gauged device's data allow the sensor's application for fine dust measurement scenarios. [3] Aside from particulate matter measurement, the TECO Envboard can be used as generic sensor platform, e.g. as an easy to use data source for any sensor-related research and development.

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