European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

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New Sensing Technologies for Air Quality Monitoring

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4 YEAR EXPERIENCE OF APPLICATION LOW-COST SENSORS IN BELGRADE IN FRAMEWORK OF CITI-SENSE PROJECT

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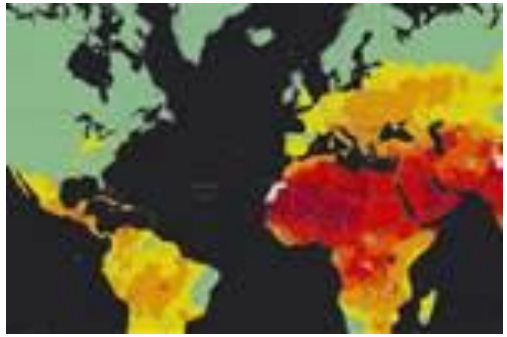
Introduction

- Air pollution is not constant in level and composition, varies through space and time and stems from both anthropogenic and natural emissions.
- Premature death, attributable to air pollution, happens mostly due to heart disease and stroke, followed by lung diseases and cancer, WHO (2014). In addition, air pollution is associated with increase in incidence of numerous additional diseases.
- IACR designated outdoor air pollution as a Group 1 carcinogenic substance and RPM mixture was evaluated separately and also classified in the Group 1 (IACR, 2013).

Air quality is important for citizens well-being



- WHO established air quality guideline in 2006.
- 10 years after air pollution is the single largest environmental health risk in Europe (EEA, 2015)
- It is estimated that level of regulated air pollutants in most European cities are far above the air quality guidelines values (EEA, 2015).
- Serbian Environmental Agency (SEPA) reported that more than 30% of citizens of Serbia were exposed to air that is considered not healthy in 2014.
- Few day ago - A new WHO air quality model confirms that 92% of the world's population lives in places where air quality levels exceed WHO limits.

Estimation of AQ in European cities and information for public

Question: How useful are such information ?

As such, citizens are at risk to be exposed to potentially harmful levels of air pollutants.

More and more cities provide timely air quality information to the public through printed and electronic media including web pages and mobile apps

Air quality data at individual level is still a rarity

- The information on the AQ and related hazards is currently mostly generic, and seldom personally relevant.
- It would be necessary to offer information to a person about AQ level in microenvironment, on the route and what does that mean for her/him.
- Ultimate importance for citizens to recognize the problem and to change behavior related to their contribution and their exposure to air pollution.

The CITI-SENSE project concept

CITI-SENSE is developing “citizens’ observatories” to:

- ✓ *empower citizens to contribute and participate in environmental governance*
- ✓ *enable them to support and influence community and societal priorities and associated decision making.*

The concept of CITI-SENSE rests on three pillars:

(i) *technological platforms for distributed monitoring;*

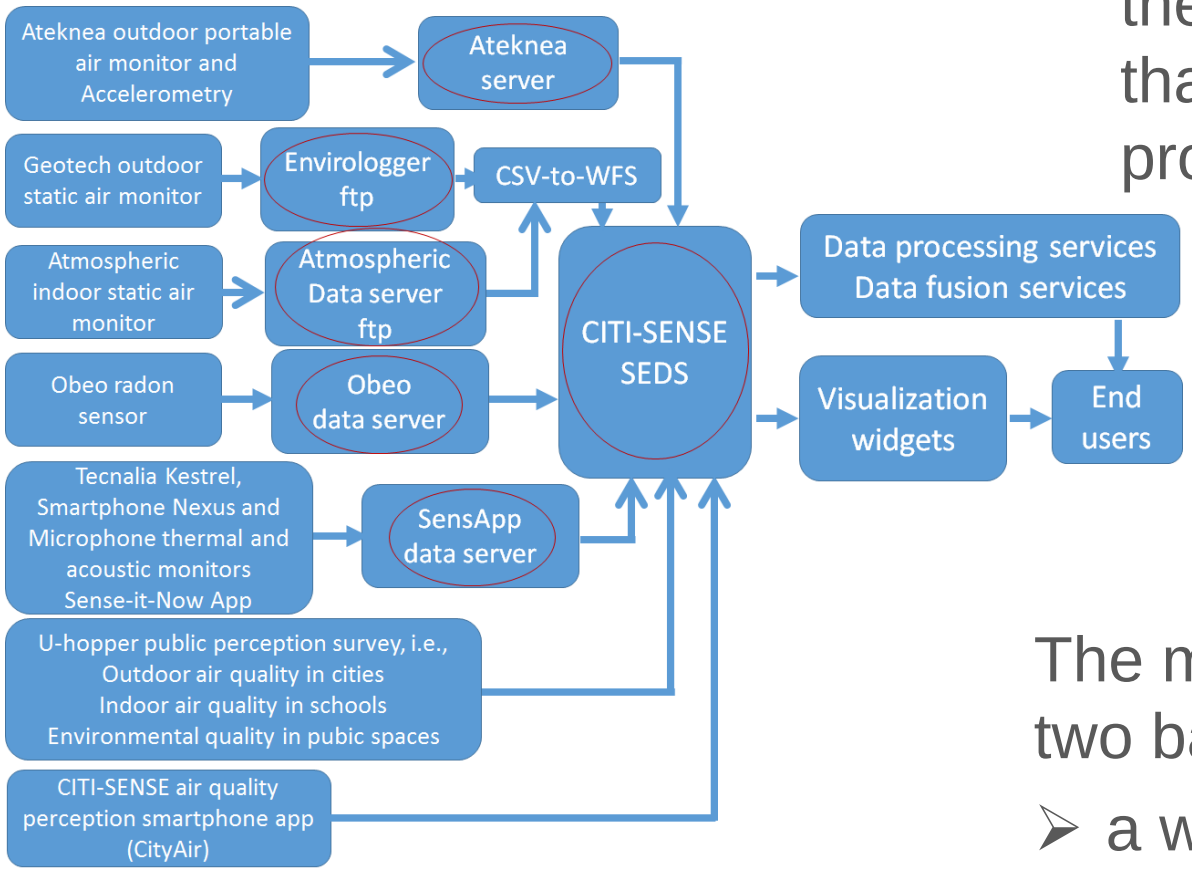
(ii) *information and communication technologies;*

(iii) *societal involvement*

Three multi-center case studies focus on a range of services related to environmental issues of societal concern performed in 8 cities:

- *combined environmental exposure and health associated with ambient (outdoor and indoor) air quality,*
- *noise and development of public spaces,*
- *and indoor air at schools.*

CITI-SENSE - Information and communication technologies



CITI-SENSE platform data flow

These products are building on the various support services that actually enable the products to function such as :

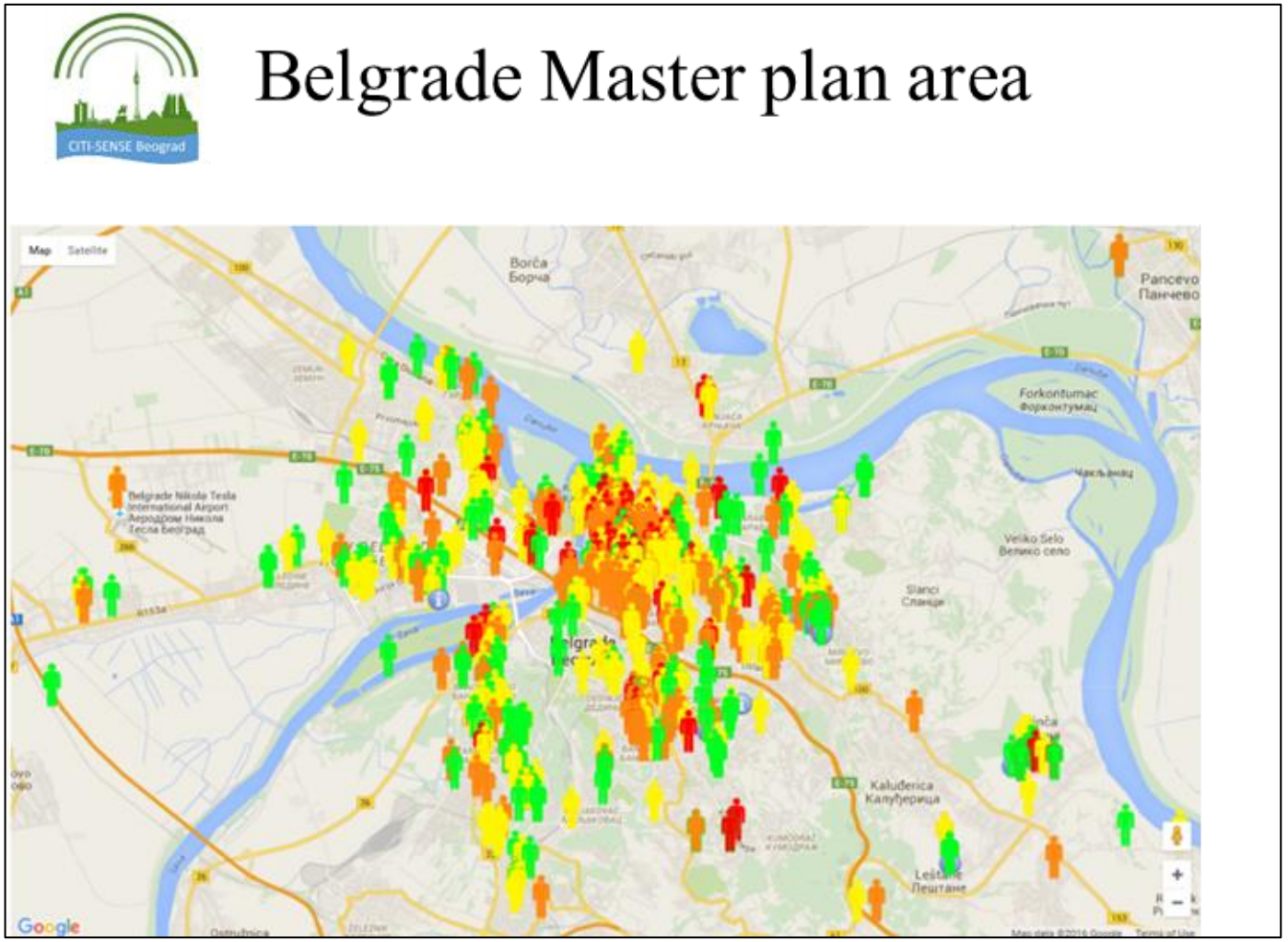
- ✓ sensor platforms,
- ✓ GIS,
- ✓ WMS,
- ✓ mathematical modeling

The main products fall into two basic types:

- ➢ a web application
- ➢ and a smart phone/mobile device application.

CITI-SENSE - societal involvement

EXAMPLE: Building a map of subjective perception of air quality in cities



CityAir is a smartphone app for the public to express their perception of the outdoor air quality at their location, and indicate sources of reduced quality

CITI-SENSE - Technological platforms for distributed monitoring

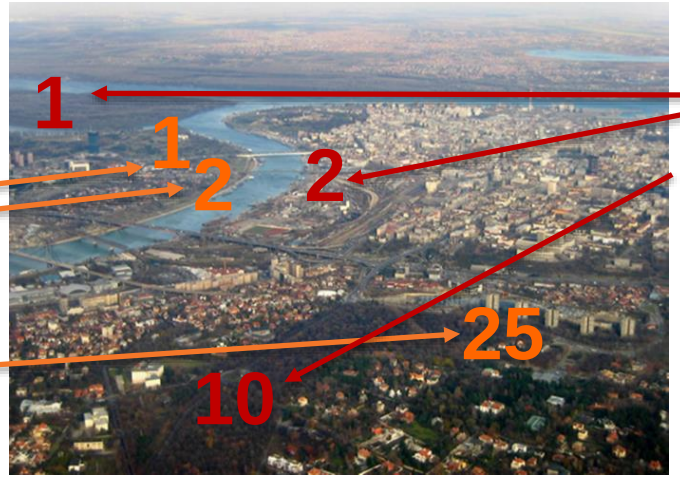
Application of low-cost sensors/platforms in Belgrade

AQMesh,

Environmental Instruments (EI) (UK)

ATMOSPHERIC Platform

ATMOSHERIC SENSORS (UK)



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EB700

Dunavnet (Serbia)

LEO

ATEKNEA (Spain)

Application of low-cost sensors/platforms in Belgrade – intergrated gas sensors

Gas	CO	NO2	NO	O3	CO2
Sensor technology	Electrochemical				Infrared
Measuring range	0-5000 ppb	0-2000 ppb	0-200 ppb	0-200 ppb	0-5000 ppm
Sensor type	CO-B4	NO2-B42f	NO-B4	• OX-B421	IRCA1

Sensor provider: ALPHASENSE, UK

AQMesh,

EI (UK)

ATMOSPHERIC Platform

ATMOSHERIC SENSORS (UK)

EB700

Dunavnet (Serbia)

LEO

ATEKNEA (Spain)

Application of low-cost sensors/platforms in Belgrade – integrited PM sensors

EB700

Dunavnet (Serbia)

AQMesh,

EI (UK)

ATMOSPHERIC Platform

ATMOSHERIC SENSORS (UK)

	AQMesh	Atmospheric	EB700
Method	Light scatering	Light scatering	Laser pc counter
Range (µm)	0.3 – 30	0,38-17	> 0,5
Sensitivity	< 1µm	n.a.	n.a.
Channels	32	16	n.a.
Flow rate	0.5 LPM	1.2 LPM	n.a.
Concentration and count range	$2x10^6$ (pc/L), PM2.5: 0-500 PM10: 0-1000 (pc/cm3)	Max pc count rate: 10^5 /s	n.a.
Price	n.a.	300 EUR	425 $
Provider	AQMesh	Alphasense	Dylos
Type		OPC-N2	Dylos pro 1700

Application of low-cost sensors/platforms in Belgrade – integrited PM sensors

EB700

Dunavnet (Serbia)

AQMesh,

EI (UK)

ATMOSPHERIC Platform

ATMOSHERIC SENSORS (UK)

- All three devices for estimation mass concentration converting PM10 and PM2.5 particle counts into PM mass-based fractions assuming a spherical particle shape and standard density.

Application of low-cost sensors/platforms in Belgrade – Colocation at ATMs

AMS Stari Grad

AMS Stari Grad

AMS SEPA

AMS Novi Beograd

Application of low-cost sensors/platforms in Belgrade

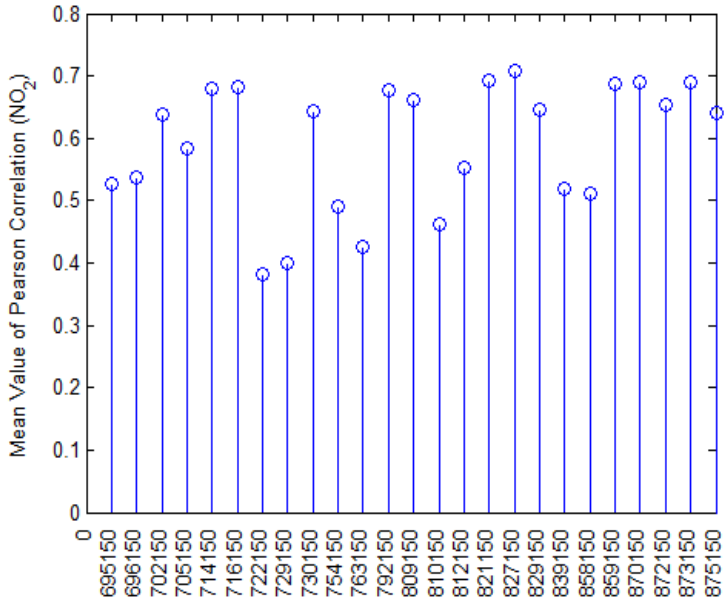
Pearson correlation coefficient within unit type EB700, AQMesh and Model 510			
	Unit type (number of units of each type depolyed in Belgrade)		
Sensor	EB700, Dunavnet (n=10)	AQmesh, Environmental Instruments (n=25)	Model 510 Atmospheric (n=12)
NO_2	0.10-0.92	0.40-0.70	0.50-0.98
NO	0.20-0.97	0.15-0.45	n.a.
CO	0.50-0.98	0.50-0.90	0.96-0.98
CO_2	0.64-0.96	n.a.	0.94-0.98
O_3	0.40-0.90	0.01-0.60	0.69-0.91
$PM_{2.5}$	0.70-0.96	0.60-0.90	0.52-0.85
PM_{10}	0.60-0.88	0.50-0.80	0.50-0.70
Meteo (T, RH, P)	>0.90	>0.90	>0.90

Application of low-cost sensors/platforms in Belgrade

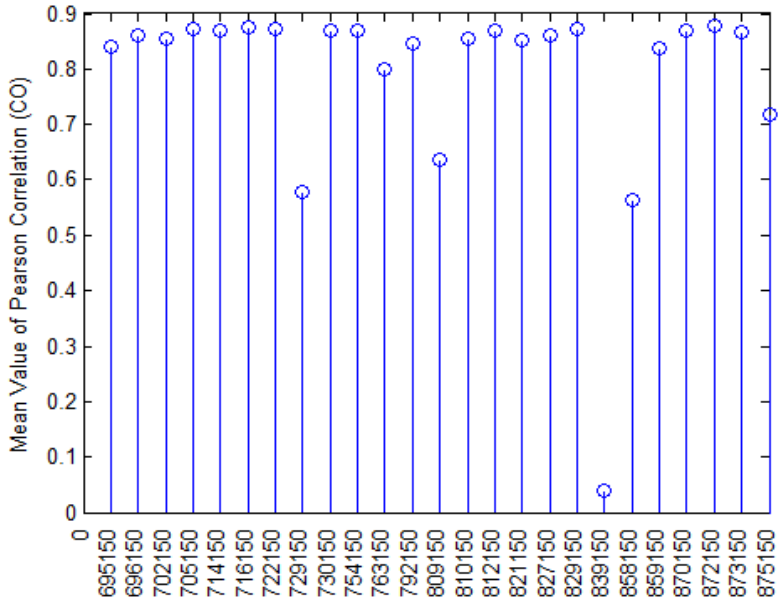
Pearson correlation coefficient between EB700, AQMesh, Model 510 collocated at and reference station Stari Grad

	Unit type (number of units of each type deployed in Belgrade)		
Sensor	EB700, Dunavnet (n=10)	AQmesh, Environmental Instruments (n=25)	Model 510 Atmospheric (n=12)
NO_2	-0.19-(-0.74)	-0.002-0.51	0.001-0.20
NO	-0.01-0.27	0.003-0.26	-
CO	0.26-0.97	0.12-0.82	0.10-0.52
CO_2	-0.41-(-0.76)	-	-
O_3	-0.04-0.52	0.18-0.85	0.07-0.33
$PM_{2.5}$	0.55-0.89	0.06-0.60	0.03-0.34
PM_{10}	0.44-0.87	-0.02-0.50	0.05-0.23
Meteo (T, RH, P)	0.91-0.99	0.15-0.97	-

Application of low-cost sensors/platforms in Belgrade



AQMesh platform - Person correlation coeficient between 25 AQMesh pods for NO2 sensor



AQMesh platform - Person correlation coeficient between 25 AQMesh for CO sensor

Artificial intelligence models for calibration of low-cost electrochemical sensor

- **Artificial neural network**s (ANN) as an example of artificial intelligence.
- Neuron-biological neuron that processes the signals across the synaptic and somatic operations. Synaptic operation is represented by multiplying each input signal x_i with the weight coefficient w_i.Then the weighted input signals are added and their sum is compared with a threshold sensitivity of neurons.
- LM algorithm has a top speed of execution, while on the other hand takes up a significant memory resources of computer during execution.
- RP-partial derivative is used to determine the direction of weight coefficients,while the amount of the partial derivative does not take affect on the coefficients weight.
- CG method adjusts the coefficients weight according to the steepest decreasing direction in which the performance function has the fastest decline.

Artificial intelligence models for calibration of low-cost electrochemical sensor

- ANN models have developed for CO and O3 sensors.
- ANN models have been developed with three different training algorithms: LM, RP and CG.
- Neural networks have shown the ability of automatic modeling of nonlinearities in contrast to the linear regression where usage of explicit models with appropriate transformations was necessary. LM neural networks have shown the best results compared to RP, CG neural networks and multivariate linear regression method.

Conclusion

Wide application of technological platforms with low-cost sensor for distributed monitoring requires:

- integrated sensors for gases and particuate matter that have uniform response
- established efficient calibration procedures that minimally increase the price of application platforms

Thank you for your attention

http://www.citi-sense.eu/

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