

# Personal Air Quality Monitoring

**Giuseppe Anastasi**

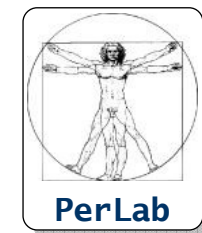
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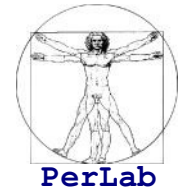
Website: [www.iet.unipi.it/~anastasi/](http://www.iet.unipi.it/~anastasi/)



UNIVERSITÀ DI PISA



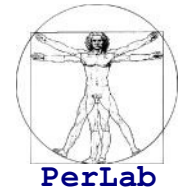
# Introduction



- Air quality has a serious impact on public health, environment and economy
  - Poor air quality results in ill health, premature deaths, as well as damages to ecosystems, crops, and buildings
  - The effects are clearly more serious in urban areas
- European countries have significantly reduced the emissions of several air pollutants
  - sulphur dioxide ( $\text{SO}_2$ ), carbon monoxide ( $\text{CO}$ ), benzene ( $\text{C}_6\text{H}_6$ ), lead ( $\text{Pb}$ )
- Other pollutants still represent a serious threat
  - particulate matter (PM)
  - ozone ( $\text{O}_3$ ),
  - Nitrogen dioxide ( $\text{NO}_2$ )
  - some organic compounds



# EEA Report 2015



EEA Report | No 5/2015

## Air quality in Europe — 2015 report

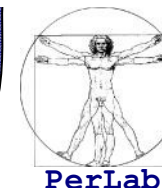
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European Environment Agency



# EEA Report 2015



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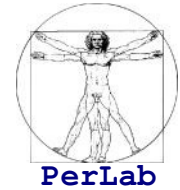
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Premature deaths due to PM2.5, O<sub>2</sub>, and NO<sub>2</sub> exposure in 2012

**Table 9.2** Premature deaths attributable to PM<sub>2.5</sub>, O<sub>3</sub> and NO<sub>2</sub> exposure in 2012 in 40 European countries and the EU-28

Country	PM <sub>2.5</sub>	O <sub>3</sub>	NO <sub>2</sub>
Austria	6 100	320	660
Belgium	9 300	170	2 300
Bulgaria	14 100	500	700
Croatia	4 500	270	50
Cyprus	790	40	0
Czech Republic	10 400	380	290
Denmark	2 900	110	50
Estonia	620	30	0
Finland	1 900	60	0
France	43 400	1 500	7 700
Germany	59 500	2 100	10 400
Greece	11 100	780	1 300
Hungary	12 800	610	720
Iceland	1 200	30	0
Italy	59 500	3 300	21 600
Latvia	1 800	80	90
Lithuania	2 300	80	0
Luxembourg	250	10	60
Malta	200	20	0
Netherlands	10 100	200	2 800
Poland	44 600	1 100	1 600
Portugal	5 400	320	470
Romania	25 500	720	1 500
Slovakia	5 700	250	60
Slovenia	1 700	100	30
Spain	25 500	1 800	5 900
Sweden	3 700	160	10
United Kingdom	37 800	530	14 100
Albania	2 200	140	270
Andorra	60	4	0
Bosnia and Herzegovina	3 500	200	70
former Yugoslav Republic of Macedonia, the	3000	130	210
Iceland	100	2	0
Liechtenstein	20	1	3
Monaco	30	2	7
Montenegro	570	40	20
Norway	1 700	70	200
San Marino	30	2	0
Serbia (*)	13 400	550	1 100
Switzerland	4 300	240	950
<b>Total (*)</b>	<b>432 000</b>	<b>17 000</b>	<b>75 000</b>
<b>EU-28 (*)</b>	<b>403 000</b>	<b>16 000</b>	<b>72 000</b>

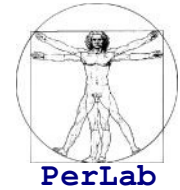
# Motivations



- Air quality typically monitored through large and expensive sensing stations
  - Located in (few) strategic locations
  - *Accurate* monitoring, but *limited* to specific areas

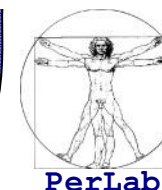


# Motivations



- Air quality typically monitored through large and expensive sensing stations
  - Located in (few) strategic locations
  - *Accurate* monitoring, but *limited* to specific areas
- Sensing stations are managed by public authorities
  - pollution data are often not (promptly) available to citizens
  - or they can be difficult to understand

# A Typical Report



## Rete Regionale Monitoraggio Qualità Aria - AGGLOMERATO NAPOLI - CASERTA (ZONA IT1507)

PROSPETTO DI SINTESI DATI DI QUALITA' DELL'ARIA AMBIENTE RILEVATI DALLE ORE 01:00 ALLE ORE 24:00 DEL 31-03-2016

POSTAZIONI	NO2 / ora [ $\mu\text{g}/\text{m}^3$ ]				CO mob / ora [ $\text{mg}/\text{m}^3$ ]			PM10 [ $\mu\text{g}/\text{m}^3$ ]		PM2.5 [ $\mu\text{g}/\text{m}^3$ ]	O3 / ora [ $\mu\text{g}/\text{m}^3$ ]				BENZENE [ $\mu\text{g}/\text{m}^3$ ]			SO2 [ $\mu\text{g}/\text{m}^3$ ]			
	max	ora	media	sup.	max	media	sup.	media	sup.	media	max	ora	media	sup.	max	ora	media	max	ora	media	sup.
Caserta CE51 Ist. Manzoni	96	21	41	0	*	*	*	28	14	19	109	15	47	0	*	*	*	*	*	*	*
Caserta CE52 Sc. De Amicis	40	9	26	0	0,8	0,4	0	29	13	10	*	*	*	*	nv	-	nv	*	*	*	*
Maddaloni CE54 Sc. Settembrini	64	19	36	0	*	*	*	41	14	16	100	15	40	0	*	-	*	*	*	*	*
Napoli NA01 Oss. Astronomico	39	12	21	0	0,5	0,4	0	27	7	11	122	17	84	0	nv	-	nv	*	*	*	*
Napoli NA02 Osp. Santobono	nv	-	nv	0	*	*	*	nv	2	nv	*	*	*	*	*	*	*	*	*	*	*
Napoli NA06 Museo Nazionale	104	9	58	0	4,1	3,1	0	nv	17	27	*	*	*	*	m	-	m	*	*	*	*
Napoli NA07 Ferrovia	112	21	66	0	0,9	0,8	0	34	12	22	*	*	*	*	0,5	10	0,2	*	*	*	*
Napoli NA08 Osp. N. Pellegrini	142	22	65	0	*	*	*	30	13	14	*	*	*	*	*	*	*	*	*	*	*
Napoli NA09 Via Argine	118	21	66	0	m	m	0	np	16	np	*	*	*	*	4,8	22	1,7	m	-	m	0
Napoli Epomeo (Tirrenopower)	np	-	np	0	np	np	0	np	*	np	*	*	*	*	*	*	*	*	*	*	*
Acerra Zona Industriale	nv	-	nv	0	1,0	0,9	0	38	13	17	*	*	*	*	nv	-	nv	4,2	8	1,5	0
Acerra Scuola Caporale	np	-	np	0	np	np	0	np	12	np	*	*	*	*	np	-	np	*	*	*	*
Aversa Scuola Cirillo	m	-	m	0	m	m	0	*	*	*	*	*	*	*	m	-	m	*	*	*	*
Casoria Scuola Palizzi (CAM)	np	-	np	0	*	*	*	np	17	np	np	-	np	0	*	*	*	*	*	*	*
Pomigliano d'Arco Area Asi	67	2	nv	0	1,3	nv	0	nv	21	nv	*	*	*	*	6,0	6	nv	4,5	1	nv	0
Portici Parco Reggia	m	-	m	0	*	*	*	m	*	m	m	-	m	0	m	-	m	*	*	*	*
S. Vitaliano Scuola Marconi	127	22	61	0	*	*	*	56	37	25	104	16	32	0	8,6	1	4,4	6,5	9	2,9	0
Torre Annunziata Sc. Pascoli	106	8	52	0	*	*	*	*	*	*	59	15	26	0	*	*	*	*	*	*	*
Volla (Tirrenopower)	np	-	np	0	np	np	0	np	*	np	*	*	*	*	*	*	*	*	*	*	*

LA STRUTTURA DELLA RETE DI MONITORAGGIO E' IN FASE DI ADEGUAMENTO AL D.LGS. 155/2010, L'ACQUISIZIONE DEI DATI ED I CRITERI DI VALUTAZIONE PER L'ANNO 2016 SONO DEFINITI DAL D.LGS. 155/2010.

### LEGENDA

\*: analizzatore non previsto  
m: analizzatore in manutenzione  
nv: dati non validabili  
np: dati non pervenuti

### Tempi di mediazione

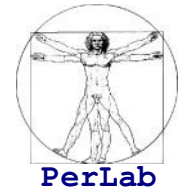
ARPAC	NO <sub>2</sub>	Biossido di azoto	massima media oraria	Il valore orario di 200 $\mu\text{g}/\text{m}^3$ non può essere superato più di 18 volte nell'arco dell'anno
	CO	Monossido di carbonio	massima media oraria	Il valore massimo della media mobile calcolata sulle 8 ore non può superare i 10 $\text{mg}/\text{m}^3$
	PM <sub>10</sub>	Polveri sosp d<10 $\mu\text{m}$	media giornaliera	Il valore giornaliero di 50 $\mu\text{g}/\text{m}^3$ non può essere superato più di 35 volte nell'arco dell'anno
	PM <sub>2,5</sub>	Polveri sosp d<2,5 $\mu\text{m}$	media annuale	Il valore medio annuale di 25 $\mu\text{g}/\text{m}^3$ non può essere superato nell'arco dell'anno
	O <sub>3</sub>	Ozono	massima media oraria	Il valore orario della soglia di informazione è pari a 180 $\mu\text{g}/\text{m}^3$ la soglia di allarme è pari a 240 $\mu\text{g}/\text{m}^3$
	C <sub>6</sub> H <sub>6</sub>	Benzene	media annuale	Il valore medio annuale di 5 $\mu\text{g}/\text{m}^3$ non può essere superato nell'arco dell'anno
	SO <sub>2</sub>	Biossido di zolfo	massima media oraria	Il valore orario di 350 $\mu\text{g}/\text{m}^3$ non può essere superato più di 24 volte nell'arco dell'anno

Dati elaborati in data

01/04/2016



# A Typical Report



ARPAT - Bollettini della di x

www.arpat.toscana.it/temi-ambientali/aria/qualita-aria/bollettini/index/regionale/22-11-2015

Info sulla logica di associazione colori - concentrazioni

Bollettino rete Regionale   Bollettino Ozono   Bollettino stazioni provinciali

Cerca

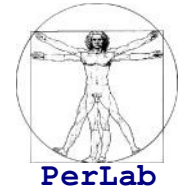
STAZIONE	COMUNE	ZONA	PM10 µg/m <sup>3</sup> media giornaliera	Numero Sup. da inizio anno	PM2.5 µg/m <sup>3</sup> media giornaliera	NO2 µg/m <sup>3</sup> max orario	SO2 µg/m <sup>3</sup> max orario	CO mg/m <sup>3</sup> max media mobile 8h	Benzene µg/m <sup>3</sup> media giornaliera	H2S µg/m <sup>3</sup> max orario
FI-GRAMSCI	FIRENZE	Agglomerato di Firenze	n.d.	10	n.d.	88	-	0.9	2.3	-
FI-SETTIGNANO	FIRENZE	Agglomerato di Firenze	-	-	-	7	-	-	-	-
FI-SIGNA	SIGNA	Agglomerato di Firenze	6	13	-	53	-	-	-	-
FI-BOBOLI	FIRENZE	Agglomerato di Firenze	8	3	-	-	-	-	-	-
FI-SCANDICCI	SCANDICCI	Agglomerato di Firenze	9	4	-	60	-	-	-	-
FI-BASSI	FIRENZE	Agglomerato di Firenze	5	2	4	52	1.5	-	n.d.	-
FI-MOSSE	FIRENZE	Agglomerato di Firenze	13	4	-	73	-	-	-	-
AR-CASA-STABBI	CHITIGNANO	Zona Collinare Montana	1	1	-	2	-	-	-	-
PI-MONTECERBOLI	POMARANCE	Zona Collinare Montana	6	0	-	9	-	-	-	40
SI-POGGIBONSI	POGGIBONSI	Zona Collinare Montana	7	0	6	32	-	-	-	-
SI-BRACCI	SIENA	Zona Collinare Montana	9	0	-	50	-	0.6	-	-

I-City-Rate-2015.pdf

Mostra tutti i download...






17:29  
23/11/2015

# How data should presented



$$AQI = \max \left\{ \frac{G_1^{meas}}{G_1^{lim}}, \frac{G_2^{meas}}{G_2^{lim}}, \frac{G_3^{meas}}{G_3^{lim}}, \dots, \frac{G_N^{meas}}{G_N^{lim}} \right\}$$

## Air Quality Index

Air Quality Index	Air Quality Classes	Color
From 0 to 0.5	Good	
From 0.5 to 1	Fair	
From 1 to 1.5	Moderate	
From 1.5 to 2	Unhealthy	
More than 2	Insalubrious	

<http://anasim.iet.unipi.it/moniqua/>



HOME    INDICE DI QUALITÀ    SOSTANZE    MAPPA

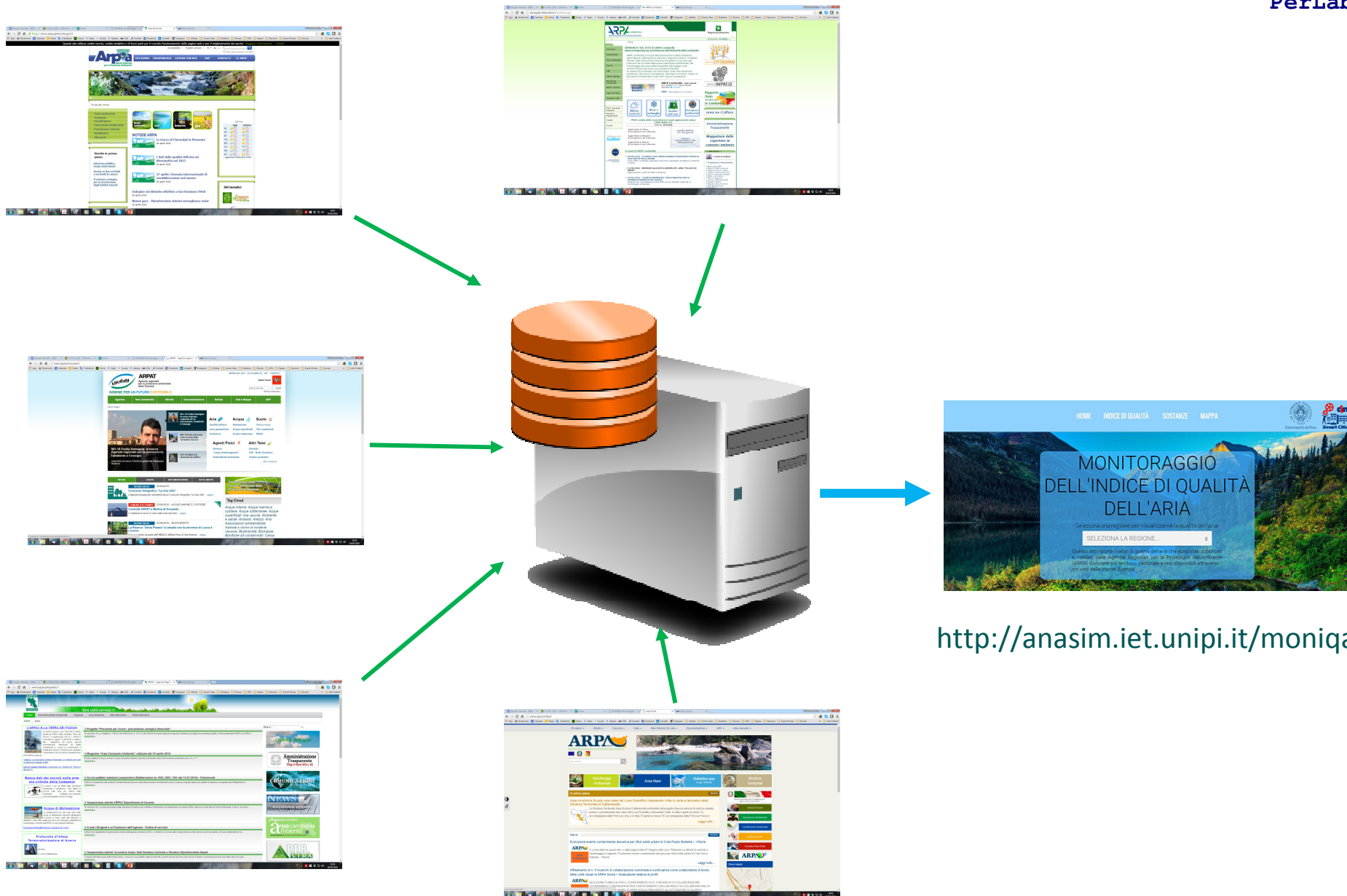
## MONITORAGGIO DELL'INDICE DI QUALITÀ DELL'ARIA

Seleziona una regione per visualizzarne la qualità dell'aria:

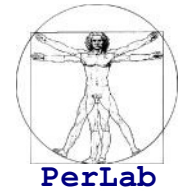
SELEZIONA LA REGIONE... 

Questo sito riporta i valori di qualità dell'aria che sono stati pubblicati e validati dalle Agenzie Regionali per la Protezione dell'Ambiente (ARPA) dislocate sul territorio nazionale e resi disponibili attraverso i siti web delle stesse Agenzie.

# MonIQA



# MonIQA



MONIQA-Monitoraggio

anasim.iet.unipi.it/moniq/#0

HOME INDICE DI QUALITÀ SOSTANZE MAPPA

UNIVERSITÀ DI PISA Smart Cities

Filtri:  
 NO<sub>2</sub>  
 NO  
 O<sub>3</sub>  
 PM10  
 CO  
 PM2.5  
 SO<sub>2</sub>  
 BENZENE

LEGENDA  
Indice di qualità dell'aria

- Buona
- Discreta
- Mediocre
- Scadente
- Pessima

# MonQA (December 2015)

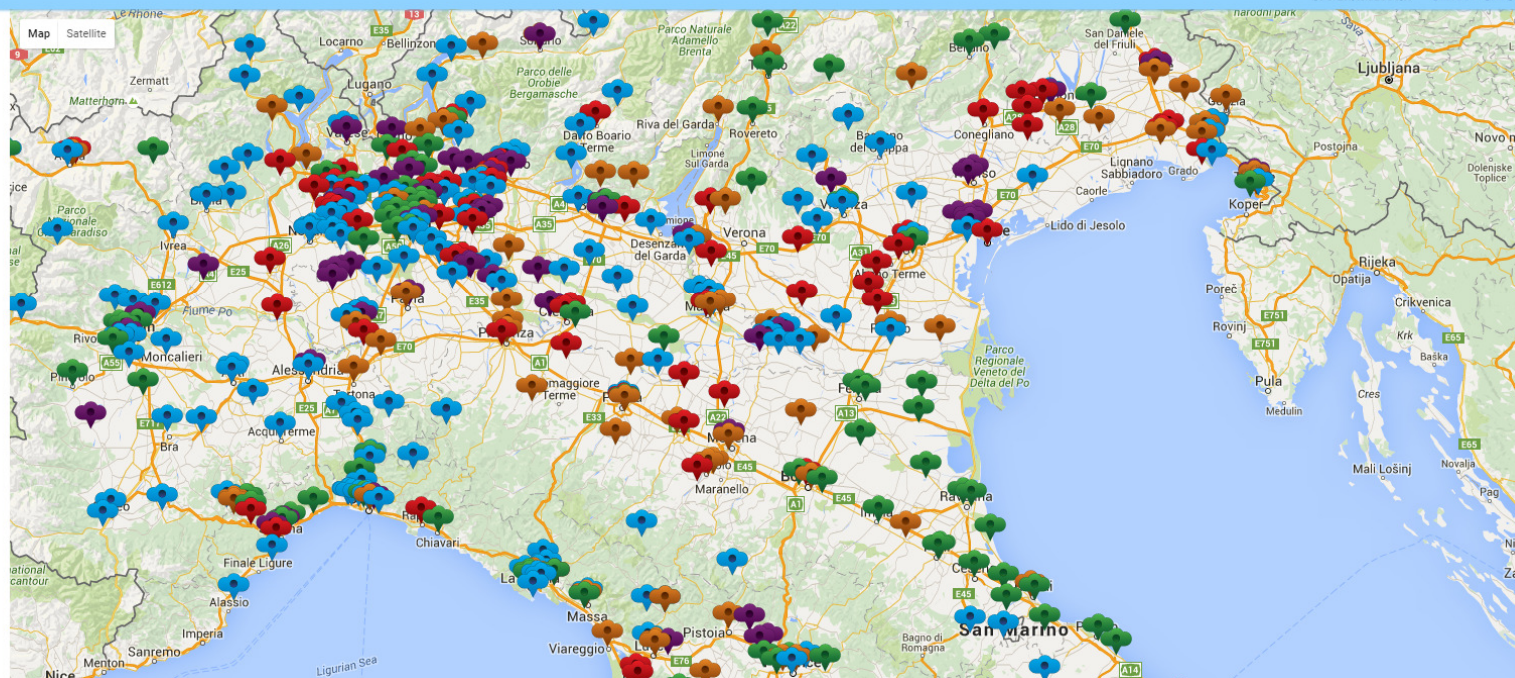


HOME INDICE DI QUALITÀ SOSTANZE MAPPA

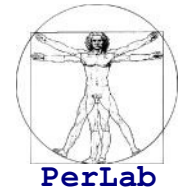


- Filtri:
- NO<sub>2</sub>
  - NO
  - O<sub>3</sub>
  - PM10
  - CO
  - PM2.5
  - SO<sub>2</sub>
  - BENZENE

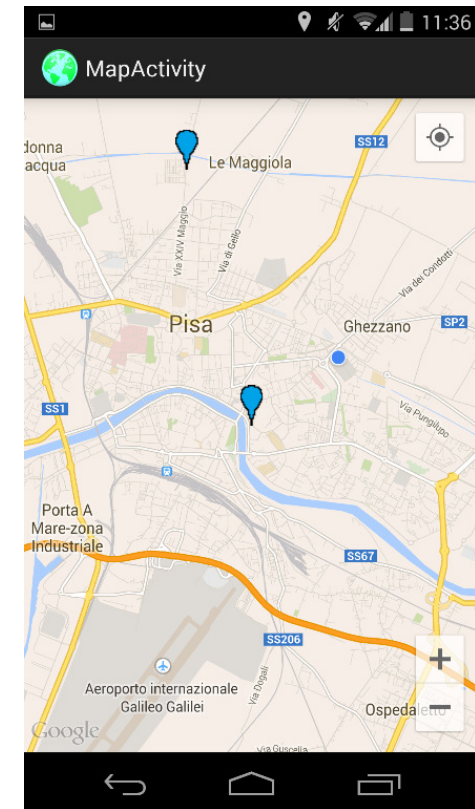
- LEGENDA  
Indice di qualità dell'aria
- Buona
  - Discreta
  - Mediocre
  - Scadente
  - Pessima



# MonIQA for Mobile Devices

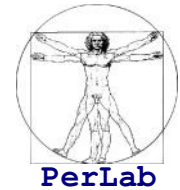


App available in



Versione Web: [anasim.iet.unipi.it/moniqua/](http://anasim.iet.unipi.it/moniqua/)

# MonQA for Mobile Devices



App available in  Google play



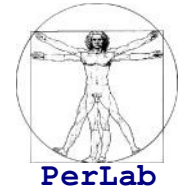


# Cooperative Sensing



U-sense  
2013

# Other Motivations

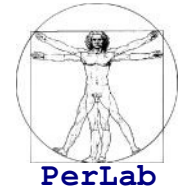


- Sensing stations are managed by public authorities
  - pollution data are often not (promptly) available to citizens
  - or they can be difficult to understand
  
- People are really interested in knowing air quality in places where they live
  - street where their home is located
  - school of their kids
  - working place
  - public gardens
  - ...

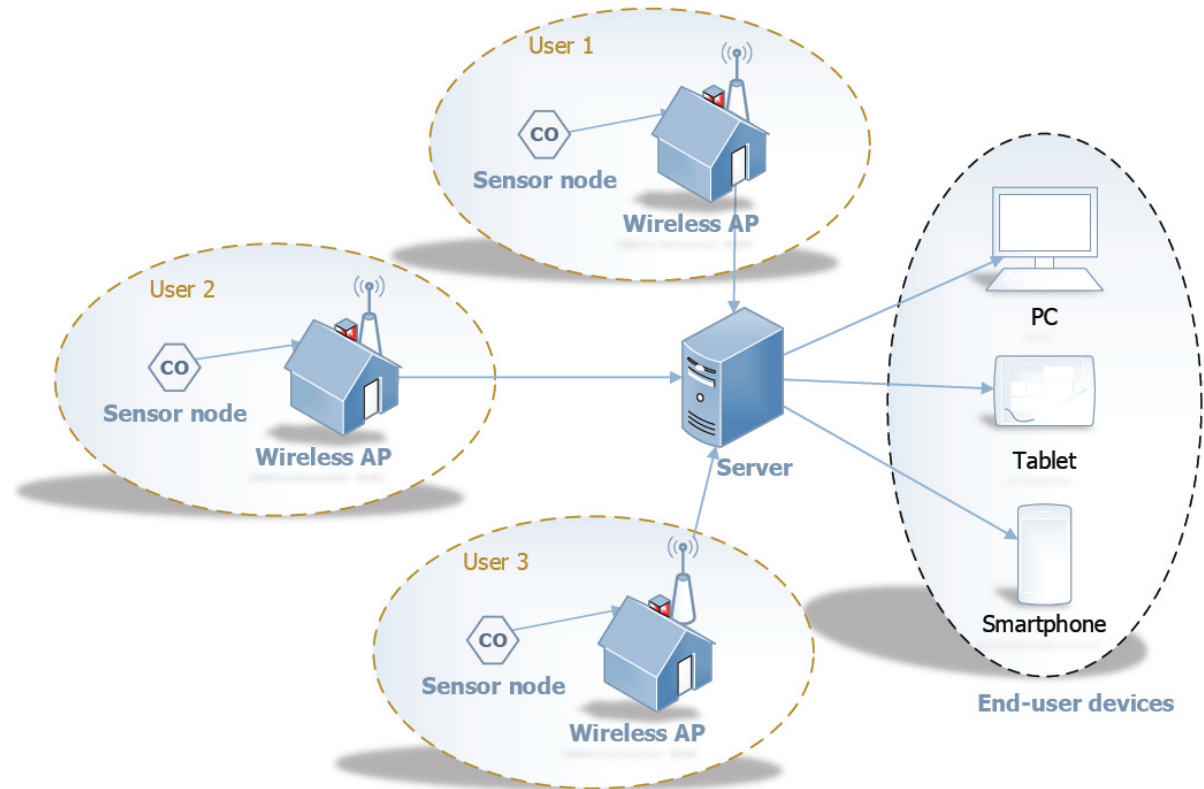


- Based on low-cost sensor nodes
  - equipped with appropriate gas sensors
  - privately installed by citizens (group of citizens)
    - ⇒ Balcony, Garden, ...
- Sensor nodes are powered by batteries
  - flexible deployment and easy relocation
- Users can share their measurements
  - through social networks (cooperative sensing)
- Real-time and fine-grained monitoring
  - Many low-cost sensors

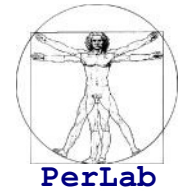
# uSense: Architecture



- Real-Time Air Quality Monitoring
  - Where the users really live



# Services to City Users



- Through a web interface, a user can:
  - View pollution map



U-sense

Nome utente

Home Mappa dei Sensori Ricerca Percorso Zone di Inquinamento U-sense

Mappa Satellite

Clicca su un marker per avere informazioni sulla qualità dell'aria nel punto selezionato

Nome utente

Home Mappa dei Sensori Ricerca Percorso Zone di Inquinamento U-sense

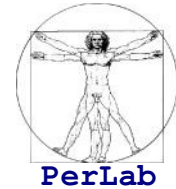
**Sensor id: 3**  
**Indirizzo:** Piazza dei Cavalieri, 6  
**Città:** Pisa  
[Mostra i dati raccolti da questo sensore](#)

Map data ©2013 Google Termini e condizioni

Map data ©2013 Google Termini e condizioni di uso Segnala un errore nella mappa

About us Privacy policy Contact us

# Services to City Users



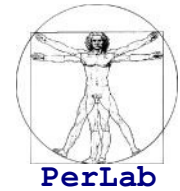
- ...Check gas concentrations in real-time



U-sense

Ora	Data	TEMP (°C)	CO (PPM)	CO2 (PPM)	NO2 (PPM)	O3 (PPB)
21:30:00	15-03-2014	12	56.172	1334.289	0.037	141.679
21:12:00	15-03-2014	12	54.003	1334.289	0.038	155.018
20:54:00	15-03-2014	12	57.994	1539.04	0.038	162.052
20:35:00	15-03-2014	12	57.46	1198.809	0.039	161.175
20:17:00	15-03-2014	12	61.743	1077.085	0.04	177.692
19:59:00	15-03-2014	12	58.265	1242.367	0.043	197.342
19:40:00	15-03-2014	12	57.46	1156.778	0.043	207.461
19:22:00	15-03-2014	12	54.706	1116.221	0.043	219.993
19:04:06	15-03-2014	12	53.32	1198.809	0.043	221.654
18:45:00	15-03-2014	12	56.937	1116.221	0.043	220.824
18:27:00	15-03-2014	12	57.197	1287.508	0.042	210.815
18:09:09	15-03-2014	12	58.265	1077.085	0.043	222.484
17:50:00	15-03-2014	13	61.743	1077.085	0.043	222.484
17:32:00	15-03-2014	13	57.46	1039.322	0.043	219.993
17:14:00	15-03-2014	13	59.661	1002.882	0.042	214.995
16:55:00	15-03-2014	13	62.053	1077.085	0.042	221.654
16:37:00	15-03-2014	14	63.005	933.792	0.041	219.993
16:19:00	15-03-2014	14	66.061	1156.778	0.042	221.654
16:00:05	15-03-2014	14	63.005	1077.085	0.041	226.626
15:42:00	15-03-2014	14	62.053	1242.367	0.041	225.799
15:24:00	15-03-2014	14	62.053	1334.289	0.041	209.978
15:05:05	15-03-2014	15	64.664	1077.085	0.04	204.94
14:47:00	15-03-2014	15	63.989	1116.221	0.038	192.25
14:29:00	15-03-2014	19	66.421	1156.778	0.036	172.506
14:10:00	15-03-2014	21	75.573	1198.809	0.033	138.986

# Services to City Users



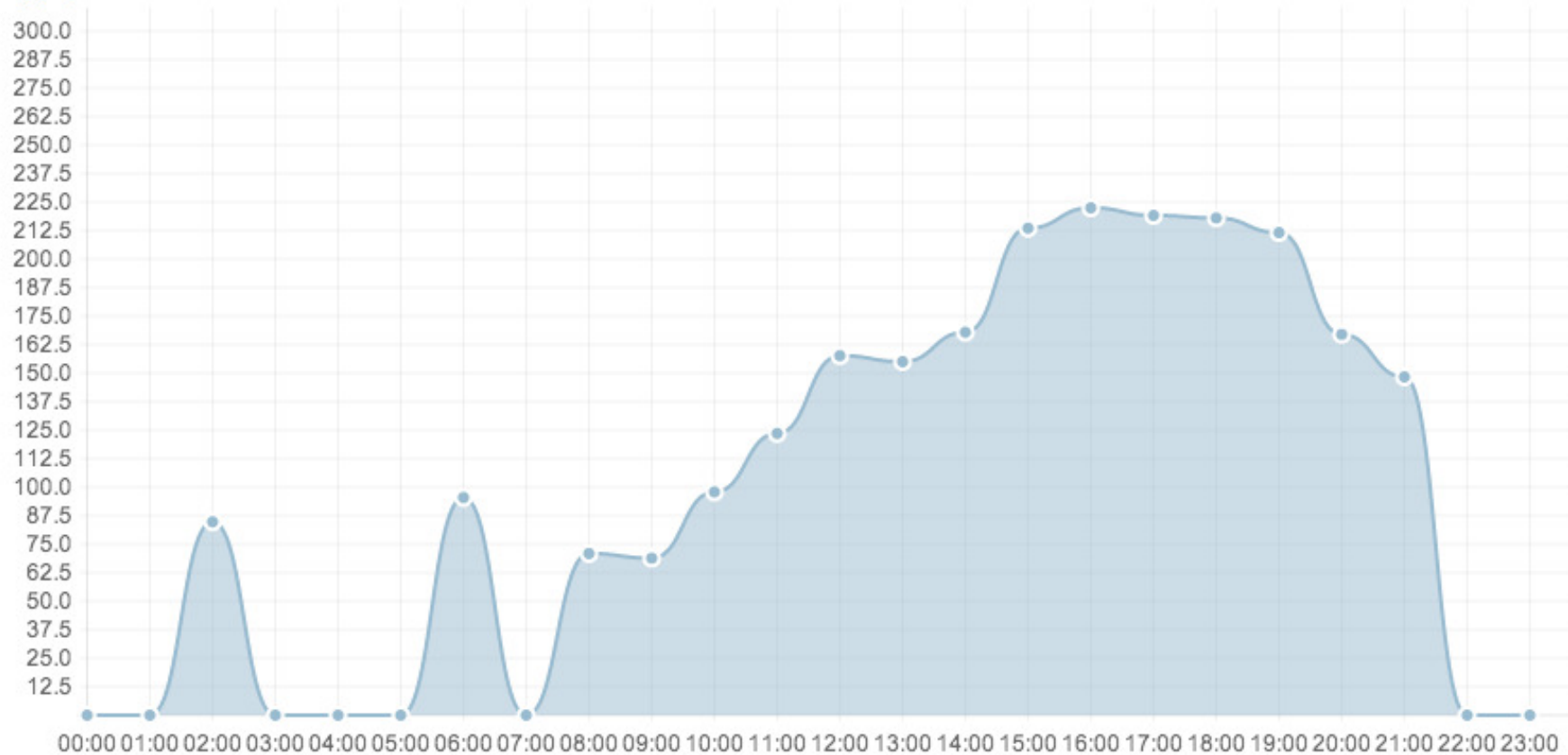
- ... and plots



**Mostra grafici:**

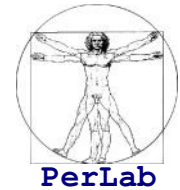
[Temperatura](#) - [Umidità](#) - [Pressione](#) - [CO](#) - [CO2](#) - [O3](#) - [NO2](#) - [VOC](#)

**O3 (ppb)**



ORA

# Services to City Users



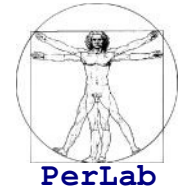
- Through a web interface, a user can:
  - Search for the less polluted route



The screenshot displays the U-sense web application interface. At the top, there is a navigation menu with options: Home, Mappa dei Sensori, Ricerca Percorso, Zone di Inquinamento, and U-sense. Below the menu, a search bar is visible with the text 'Nome utente' and a 'Log In' button. The main content area is divided into two panels. The left panel shows a map of Pisa with various colored circles (green, yellow, red) representing pollution sensors. The right panel shows a route search tool with 'Partenza: via diotisalvi, pisa' and 'Arrivo: piazza dei cavalieri, pisa'. A blue route is highlighted on the map, passing through several sensor locations labeled A through I. The bottom of the page contains a footer with 'About us', 'Privacy policy', and 'Contact us' links.



# Sensor Registration



- A user with a private sensor can:
  - Create an account
  - Register his/her sensor to the system
  - Modify the sensor location
  - Remove a sensor from the system
  - View data taken from his/her sensor directly on a dedicated page



U-sense

# U-Sense Registration Form

[Home](#)[Mappa dei Sensori](#)[Ricerca Percorso](#)[Zone di Inquinamento](#)[U-sense](#)

## Cos'è U-sense?

"Il progetto Smarty (Smart Transport for a Sustainable City) è un progetto finanziato dal governo della Regione Toscana a cui prendono parte tra i partner l'azienda toscana Softec e l'Università di Pisa, e prevede una durata che va dal 2012 al 2014. Obiettivo del progetto è la realizzazione di una piattaforma ICT che permetta lo sviluppo di servizi innovativi, promuovendo l'utilizzo di sistemi di trasporto flessibili come il car/bus pooling e il bike/car sharing."

[continua a leggere](#)

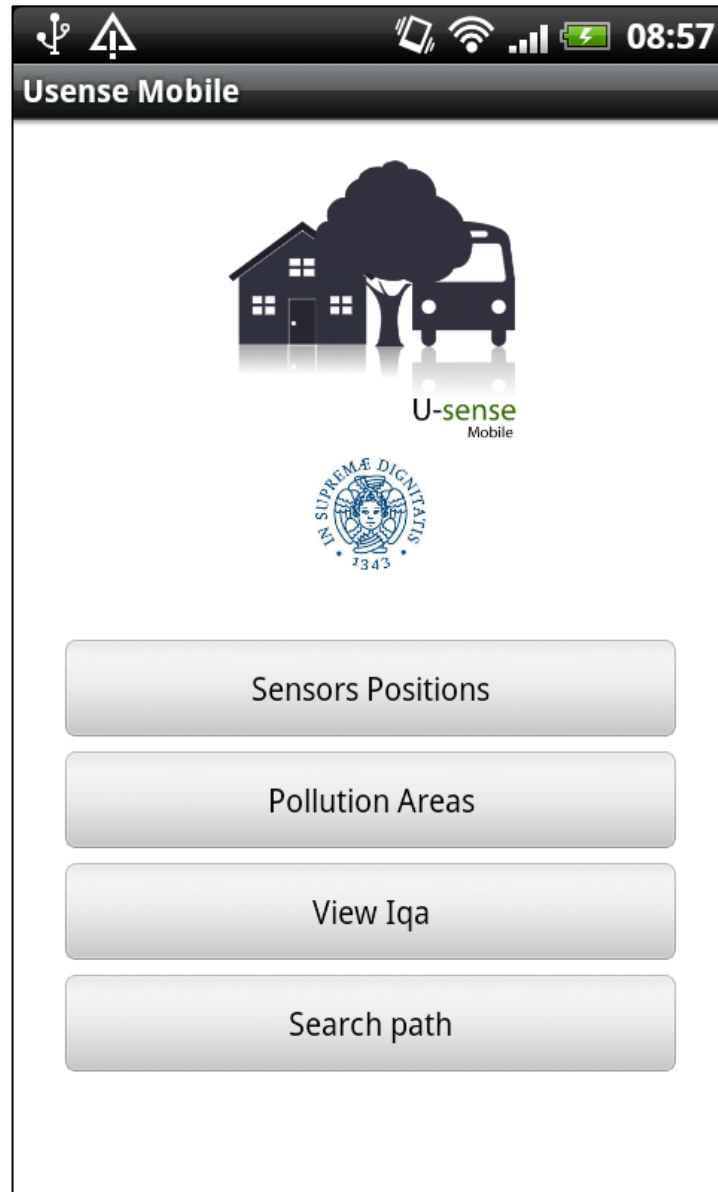
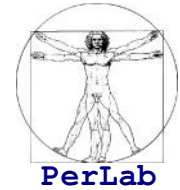
## Registrati

Il campo "Codice Amministratore" è facoltativo. Inserire solo se sei un amministratore, altrimenti lasciare vuoto

[About us](#) [Privacy policy](#) [Contact us](#)

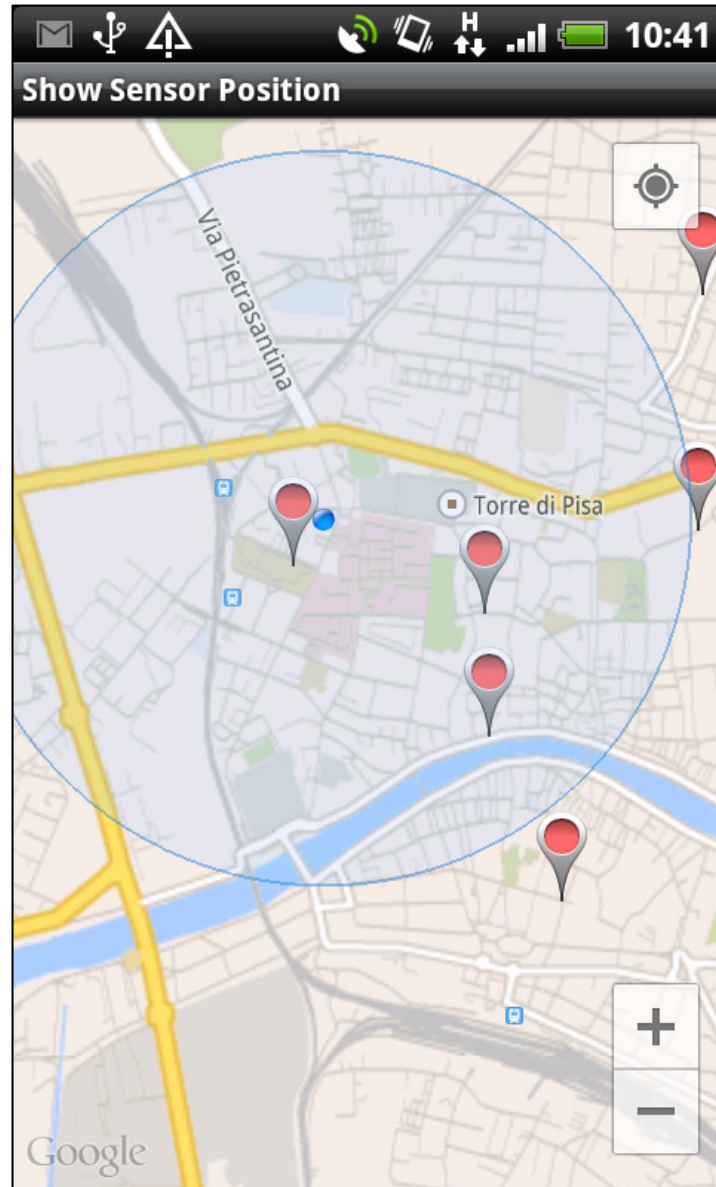
Beta version on <http://anasim.iet.unipi.it>

# Mobile Interface



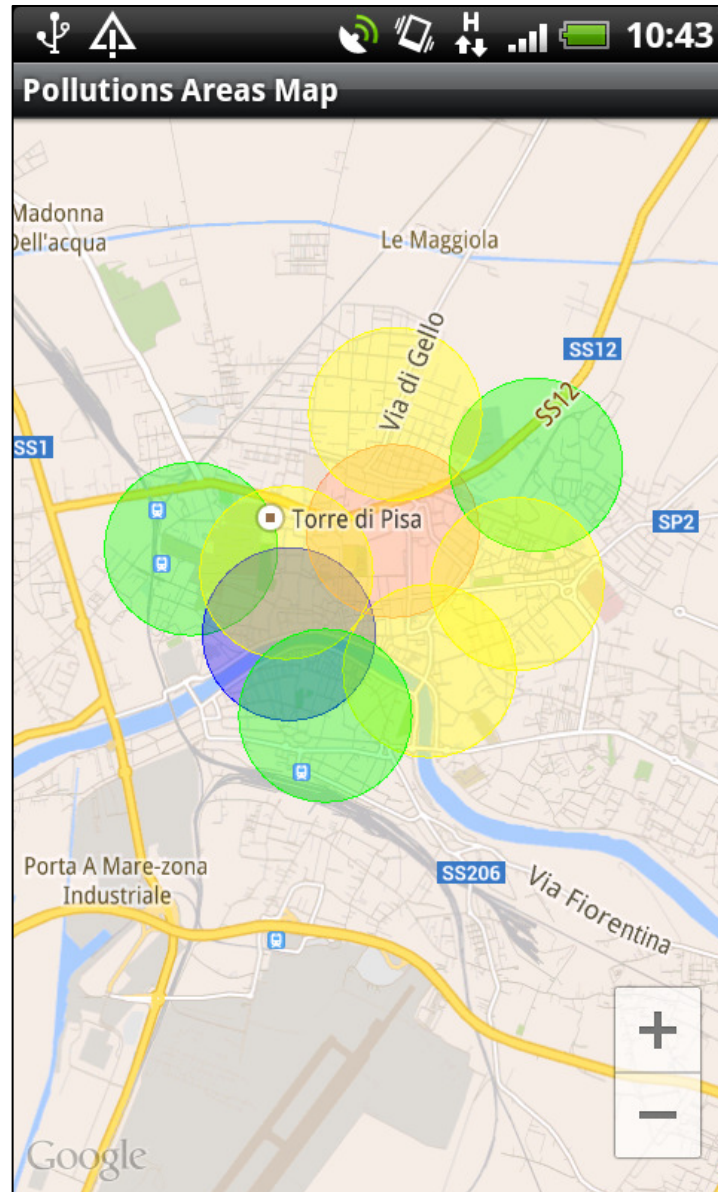
- A mobile user can
  - Visualize sensors in her/his proximity (GPS localization)
  - Check pollution areas
  - Check IQA (Air Quality Index) in real time
  - Look for less polluted paths





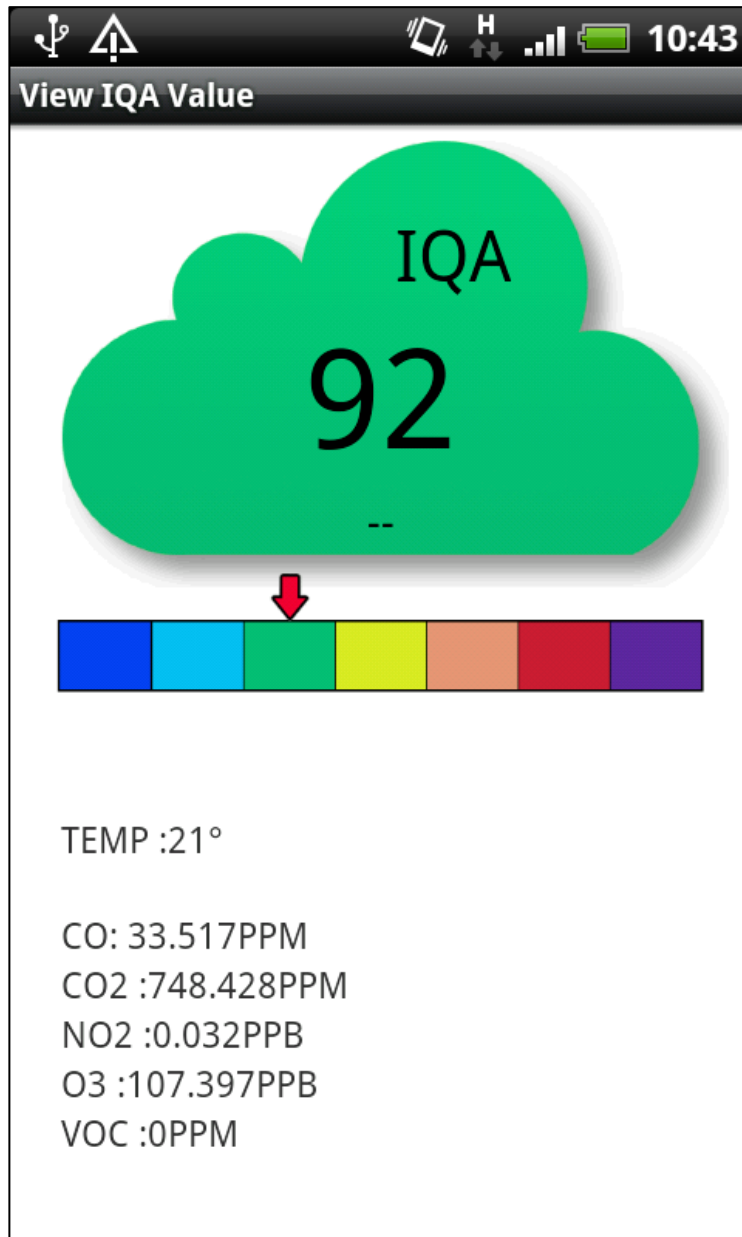
## ■ A mobile user can

- Visualize sensors in her/his proximity (GPS localization)
- Check pollution areas
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## ■ A mobile user can

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## ■ A mobile user can

- Visualize sensors in her/his proximity (GPS localization)
- Check pollution areas
- Check IQA (Air Quality Index) in real time
- Look for less polluted paths

11:16

Show Sensor Position

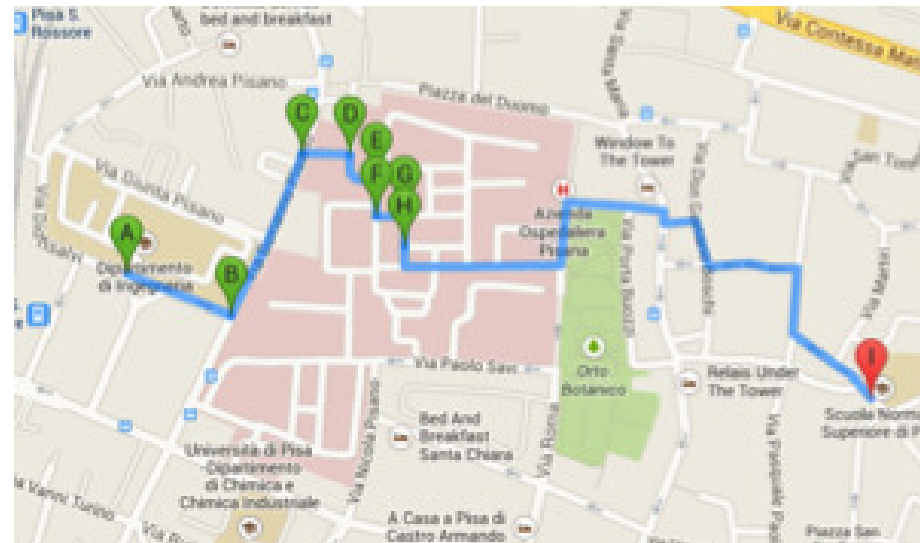
From: (ex: Via Diotalvi Pisa)

To: (ex: Piazza Garibaldi, Pisa)

Search Path

## ■ A mobile user can

- Visualize sensors in her/his proximity (GPS localization)
- Check pollution areas
- Check IQA (Air Quality Index) in real time
- Look for less polluted paths



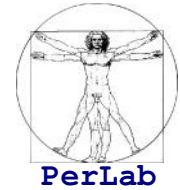
# Experimental Analysis



U-sense  
2013



# Hardware

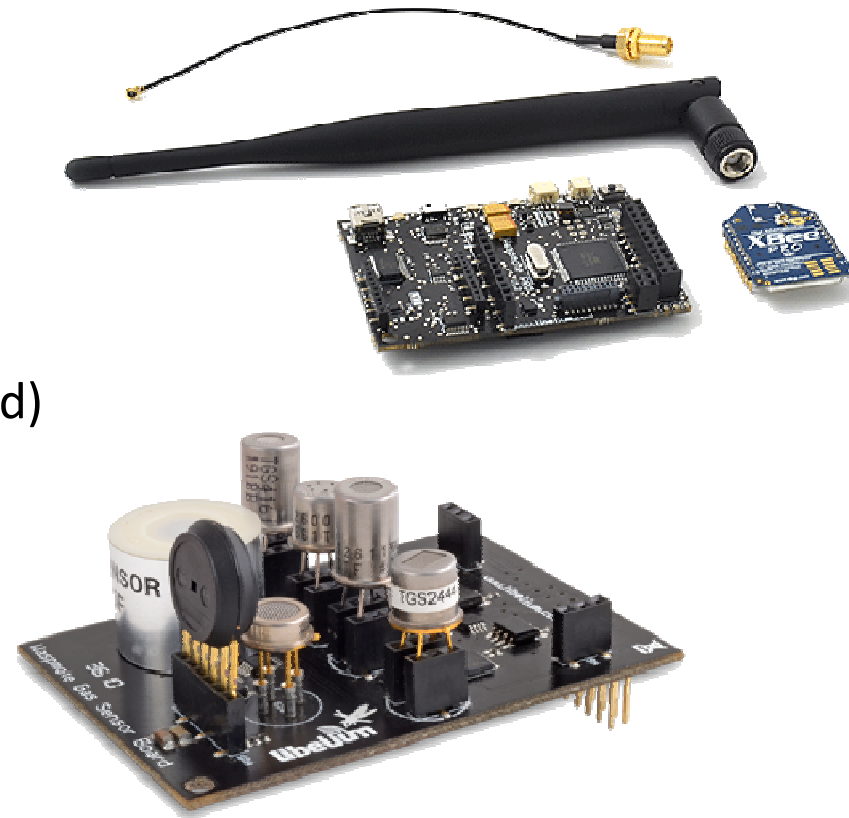


## ■ Libelium Wasp mote

- 8-bit microcontroller
- WIFI Communication module

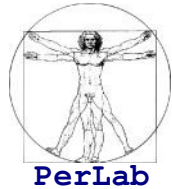
## ■ Gas sensor board 2.0

- CO (carbon monoxide)
- CO<sub>2</sub> (carbon dioxide)
- NO<sub>2</sub> (nitrogen dioxide)
- O<sub>3</sub> (ozone)
- VOC (volatile organic compound)
- Temperature
- Humidity



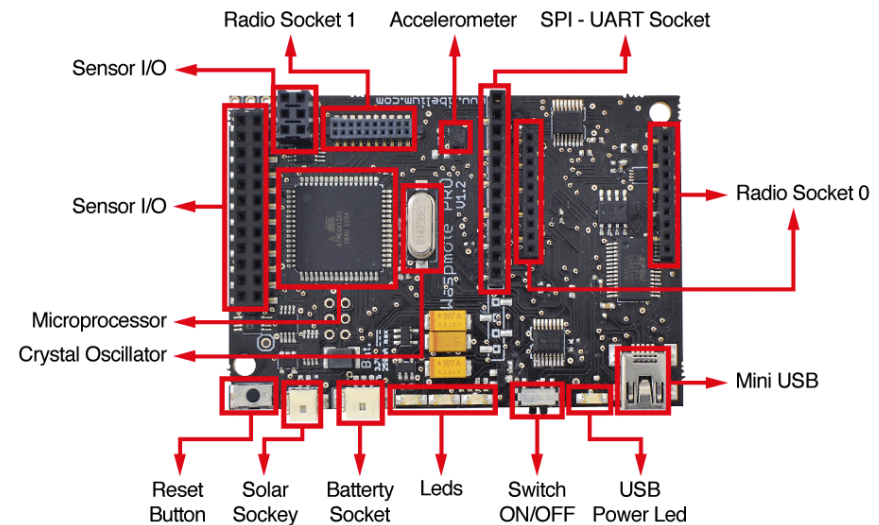
<http://www.libelium.com/>

# Wasmote

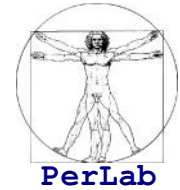


## ■ Wasmote

- 8-bit microcontroller
- Microcontroller: ATmega 1281 (low power consumption processor)
- Frequency: 14 Mhz
- SO: none
- SRAM: 8Kb
- EPROM: 4Kb
- FLASH: 128Kb
- Battery: 3,7 V – 6.600 mA/h
- Consumption:  
ON: 15 mA – Sleep: 55uA – DeepSleep: 55uA



# WiFi Module

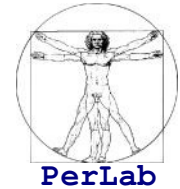


- Protocol: 802.11b/g – 2,4GHz
- TX Power: from 0 to 12 dBm, variable via software

Estate	Power Consumption
OFF	0 uA
SLEEP	4 uA
ON	33 mA
Receiving Data	38 mA
Transmitting Data	38 mA
Scanning Access Points	34 mA



# Wasmote programming



## ■ Programming:

- C language, procedural (non-object oriented).
- No threads, no multitasking
- Library for interfacing with sensors, WiFi/ZigBee module, and microcontroller.

```
mote SDutility define sendFTP sense transmissionWiFi utility
#include <WaspSensorGas_v20.h>
#include <WaspWiFi.h>

uint8_t socket=SOCKET0;
int NODE_ID=2;

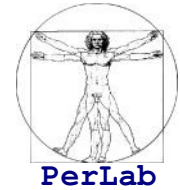
float CO_value=0.00;
float CO2_value=0.00;
float O3_value=0.00;
float NO2_value=0.00;
float VOC_value=0.00;
int PREX_value=0;
char sentence[256];

void setup()
{
  //Turn on the USB and print a start message
  USB.ON();
  //setdatetime();
  RTC.ON();
  // Setting time [yy:mm:dd:dow:hh:mm:ss]

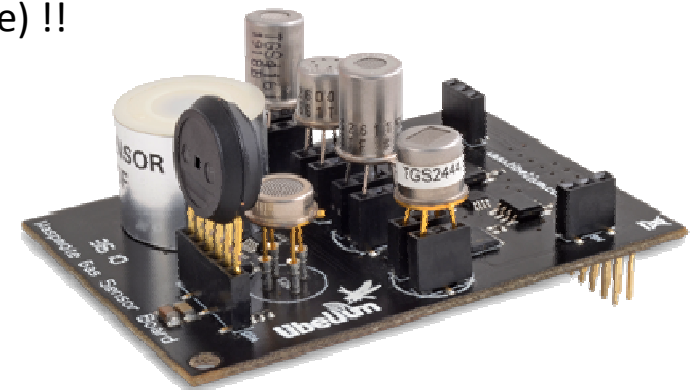
  RTC.setTime("14:03:15:04:14:08:00");
  USB.println(F("start"));
  delay(1000);
}

void loop()
{
  RTC.ON();
  Utils.setLED(LED1, LED_ON);
  //USB.println(RTC.getTime());
  RTC.ON();
```

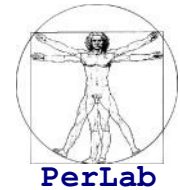
# Gas Sensor Board



- GAS Sensor Board
  - CO, CO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, VOC
  - All sensors need to be calibrated
    - ⇒ All sensors have different physical characteristics
  - From microcontroller we obtain an electrical measure
    - ⇒ Voltage or resistance value
  - Calibration is not simple, it needs a gas reference
    - ⇒ We need an artificial air with known gas concentration
  - Sensors are energy hungry
    - ⇒ All sensors have a resistance to be heated up to 400 °C !!!
    - ⇒ Power consumption is about 100 mW (on average) !!
    - ⇒ Duty cycling required



# GAS Sensor Board



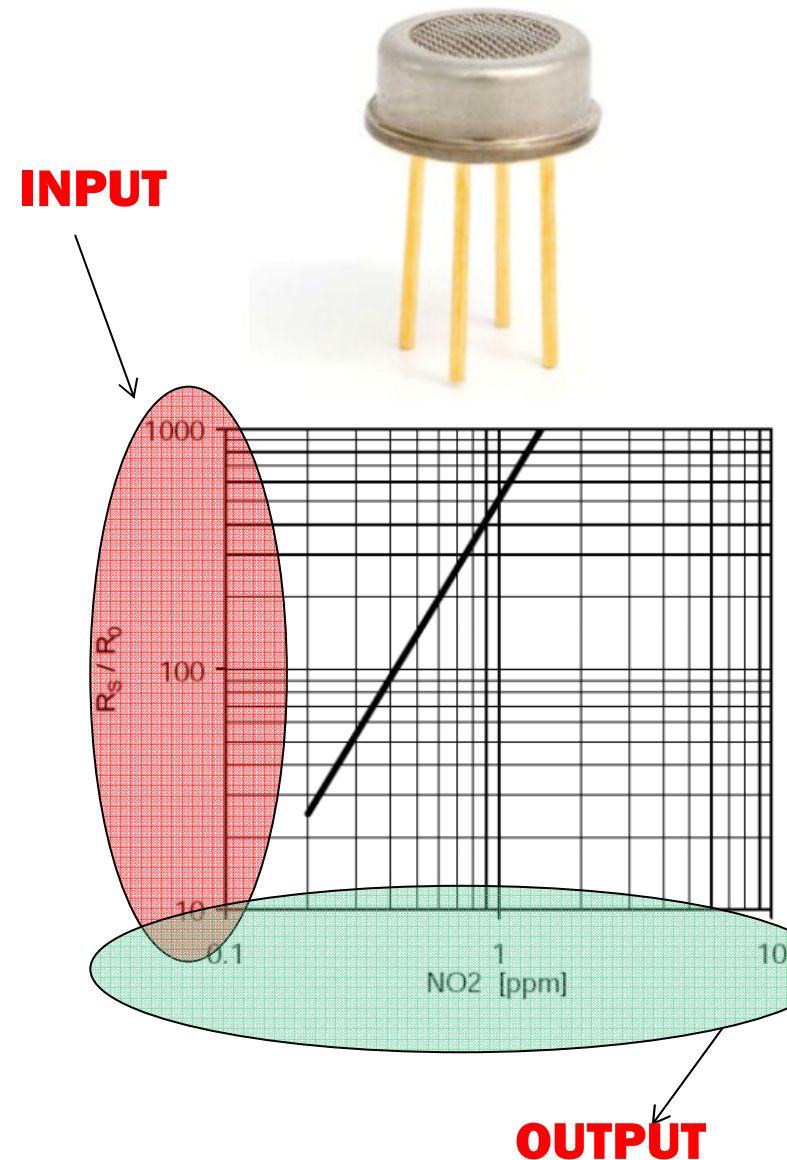
- NO<sub>2</sub> Sensors (MiCS-2710)
  - Specifications (from datasheet)

## Maximum Ratings

Rating	Symbol	Value/Range	Unit
Maximum sensor supply voltage	V <sub>CC</sub>	2.5	V
Maximum heater power dissipation	P <sub>H</sub>	50	mW
Maximum sensor power dissipation	P <sub>S</sub>	1	mW
Relative humidity range	R <sub>H</sub>	5 – 95	%RH
Ambient operating temperature	T <sub>amb</sub>	-30 – 85	°C
Storage temperature range	T <sub>sto</sub>	-40 – 120	°C
Storage humidity range	RH <sub>sto</sub>	5 – 95	%RH

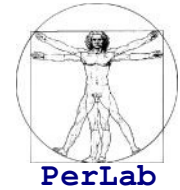
## Operating Conditions

Parameter	Symbol	Typ	Min	Max	Unit
Heating power	P <sub>H</sub>	43	30	50	mW
Heating voltage	V <sub>H</sub>	1.7	-	-	V
Heating current	I <sub>H</sub>	26	-	-	mA
Heating resistance	R <sub>H</sub>	66	59	73	Ω

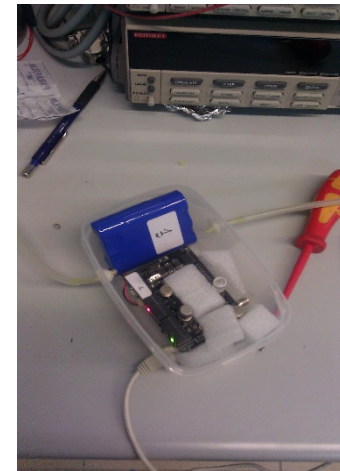


<http://www.cdiweb.com/datasheets/e2v/mics-2710.pdf>

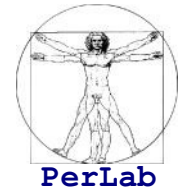
# Sensor Calibration



- We calibrated sensors in our lab



# External Box

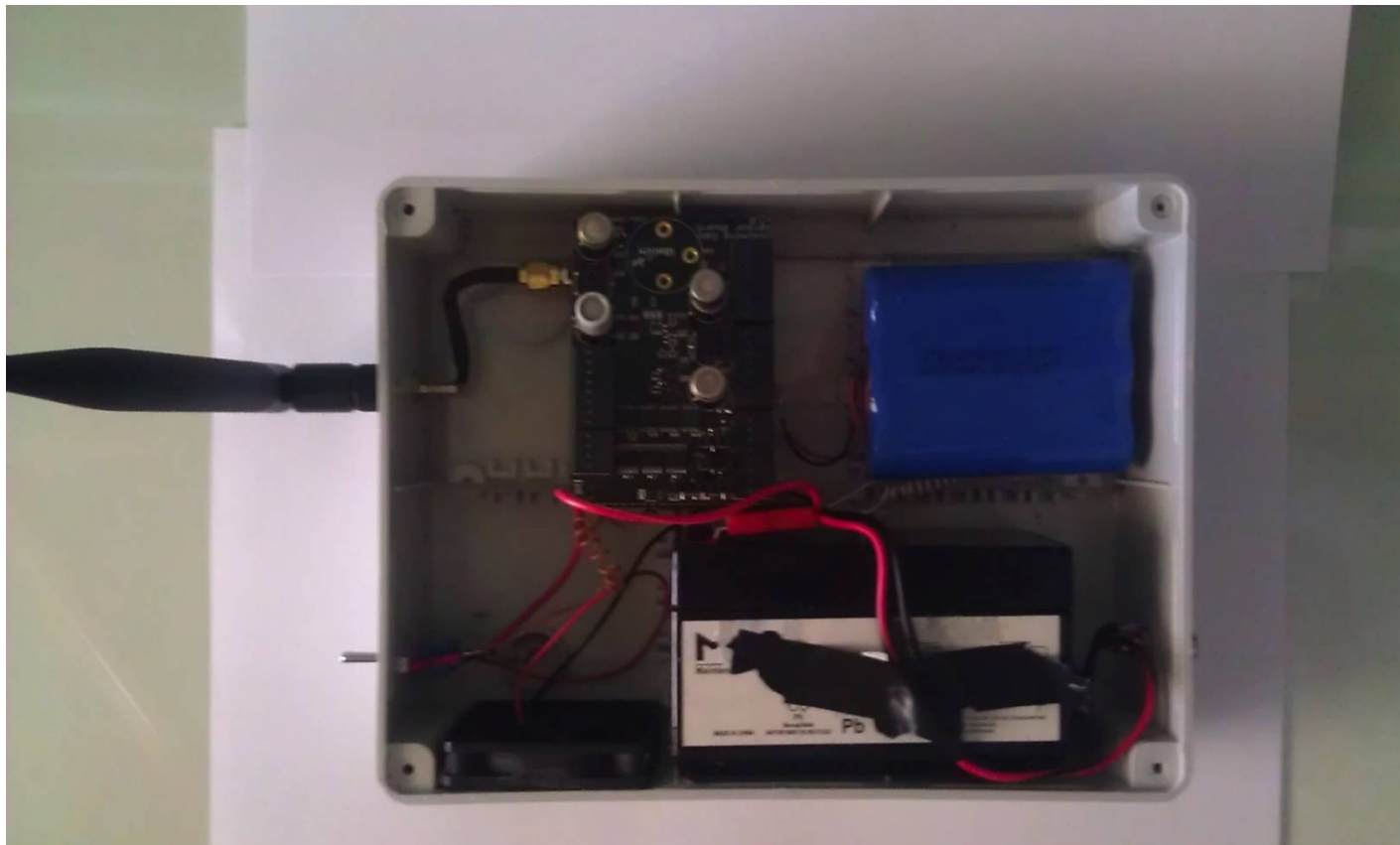


## ■ Packaging

- External PVC box
- Includes fan, activation buttons, led indicators ...
- And an extra 12V battery to power the fan

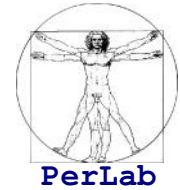


U-sense



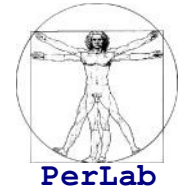


# Experimental Setup



- 30-day in-site experimentation
  - May 1-31, 2014
- Three different sensor nodes
  - Deployed in different locations
  - with different traffic conditions
  - and expected pollution levels
- Measurements
  - Gas concentration (every 30 min)
    - ⇒ CO
    - ⇒ CO<sub>2</sub>
    - ⇒ NO<sub>2</sub>
    - ⇒ O<sub>3</sub>

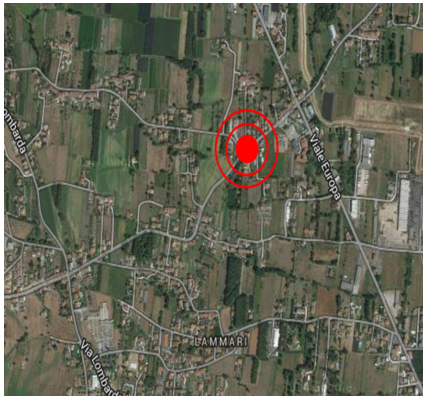
# Experimental Setup



- We considered 3 locations with different traffic conditions

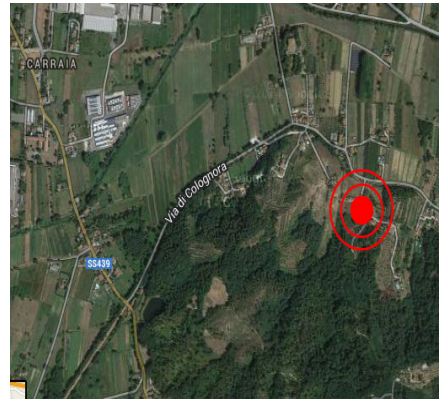
**Moderate Traffic  
Conditions**

**ZONE A**



**Low Traffic  
Conditions**

**ZONE B**

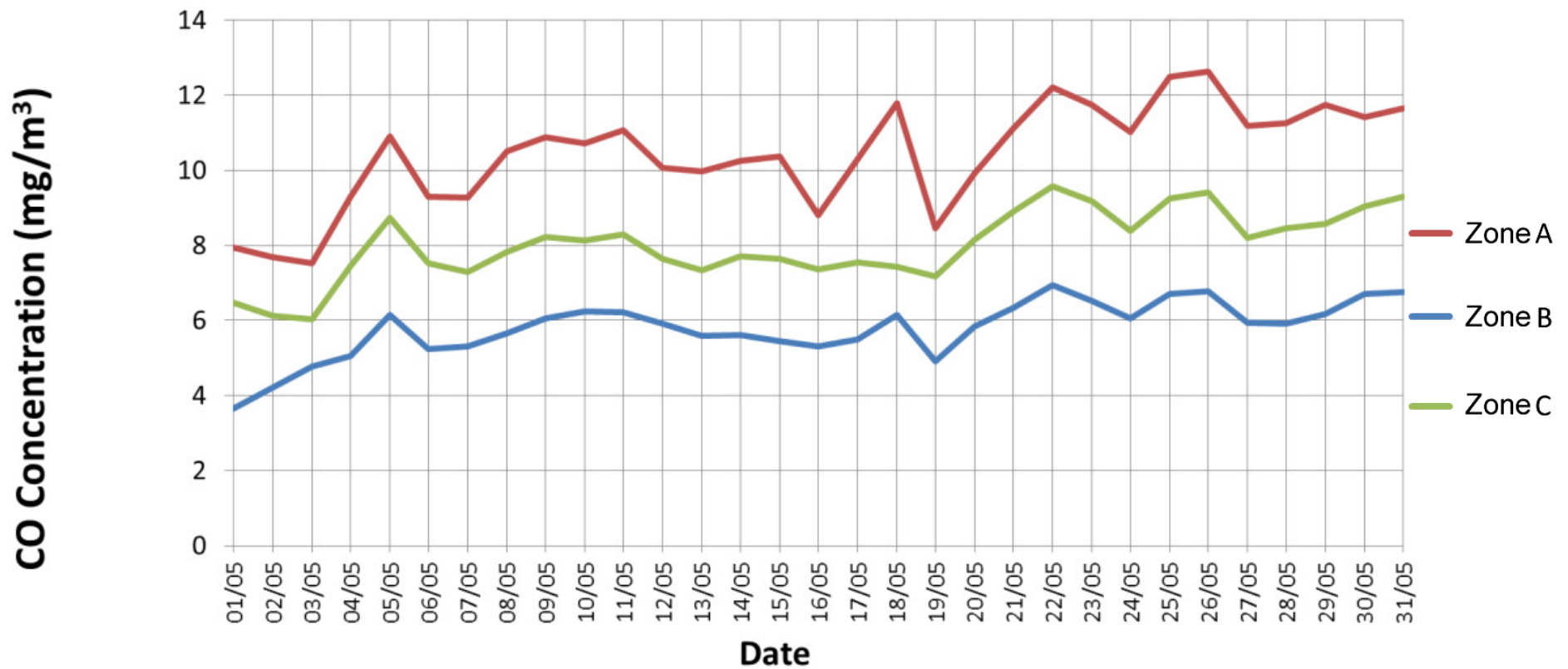
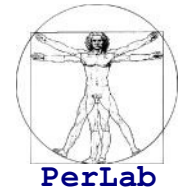


**Moderate Traffic  
Conditions**

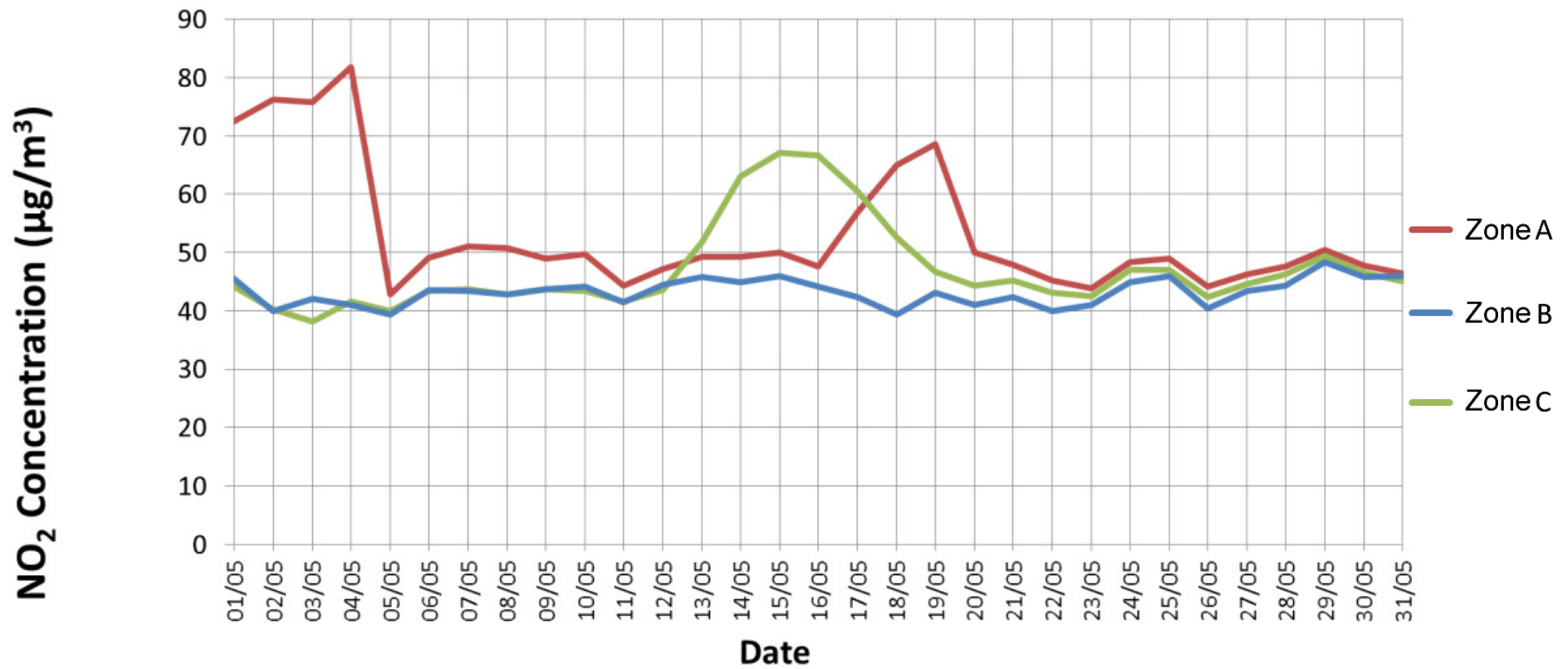
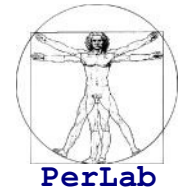
**ZONE C**



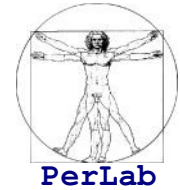
# Experimental data



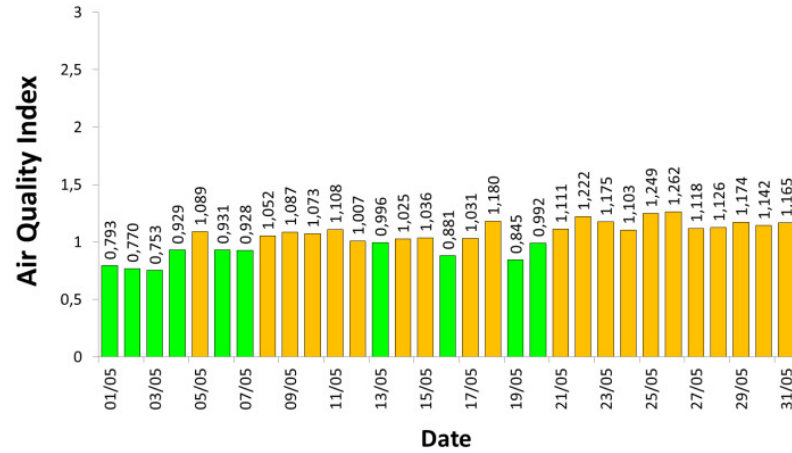
# Experimental data



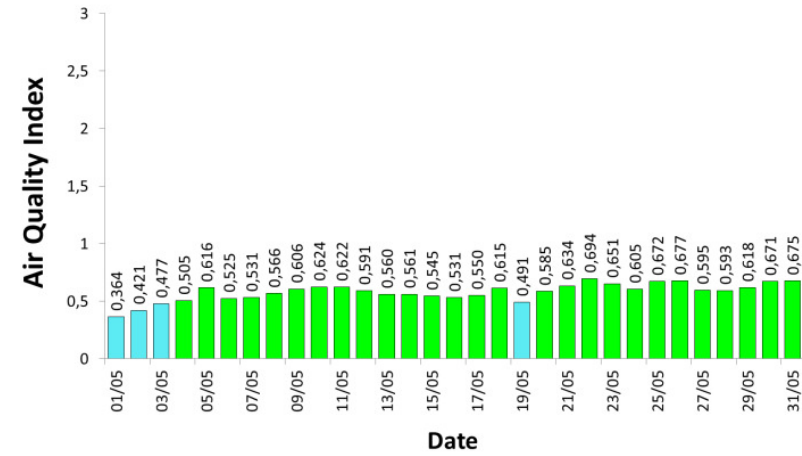
# Experimental data



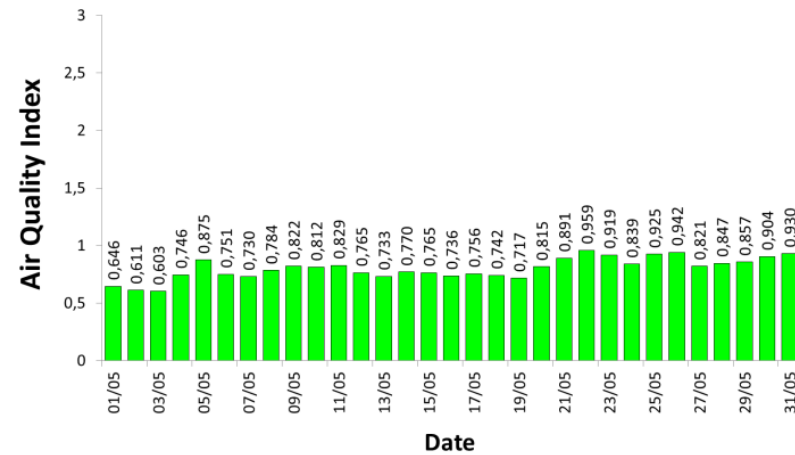
### Zone A



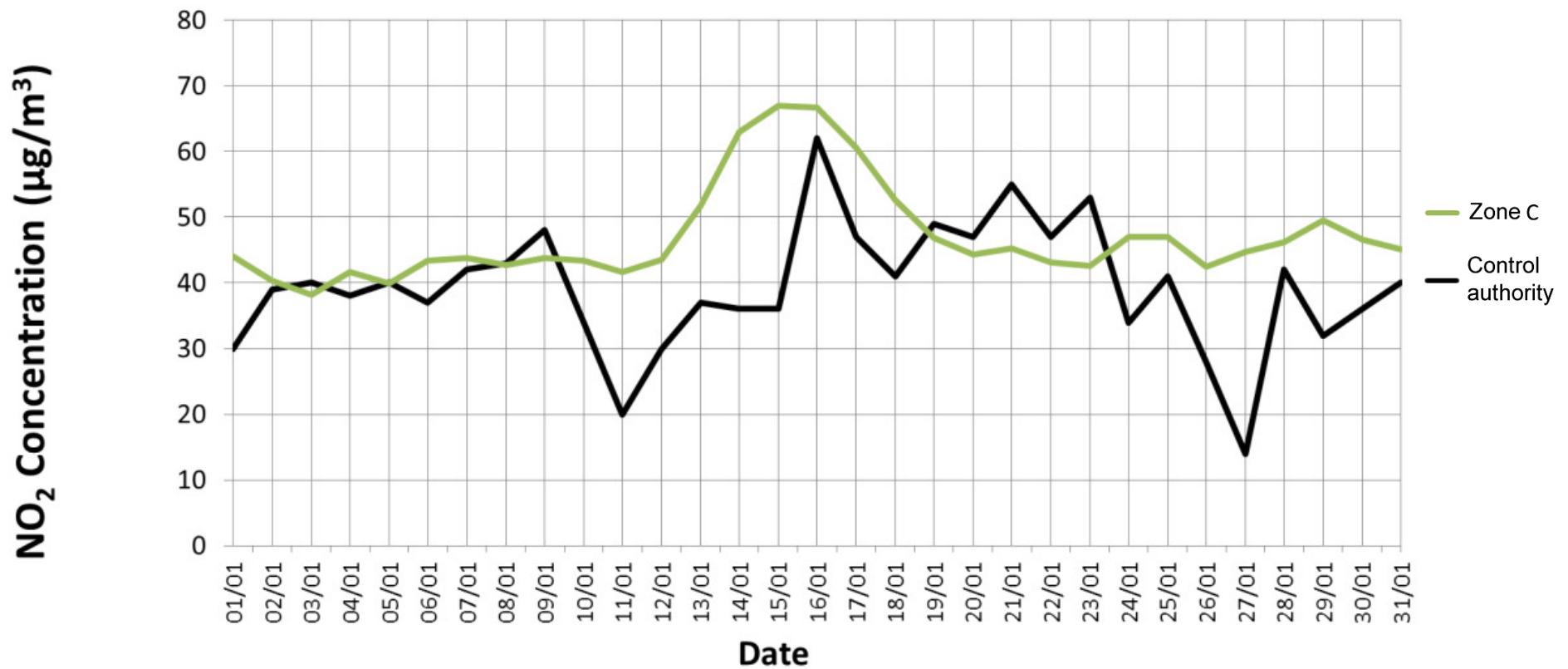
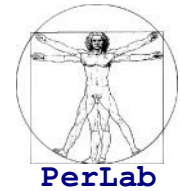
### Zone B



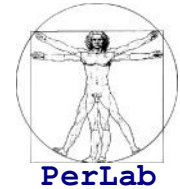
### Zone C



# Experimental data



# Next Steps



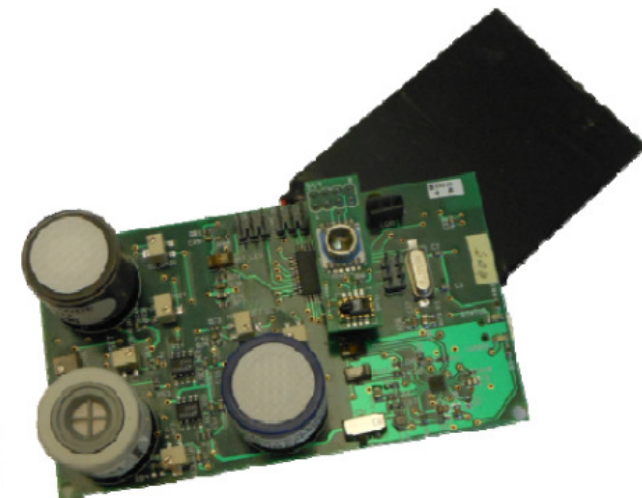
## Personal Air Quality Monitoring

- Low-cost devices based on open-platform hardware
  - Wearable sensing device connected to the SmartPhone
  - Sensing device mounted on bikes/scooters/baby strollers
  - Geo-localization and data sharing
    - through social networks
- Indoor Air Quality Monitoring



UNIVERSITÀ DI PISA

Activity Funded by University of Pisa in the  
Framework of the PRA 2015 Program



**Questions?**

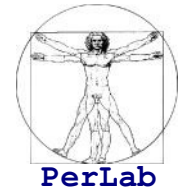




# Next Steps



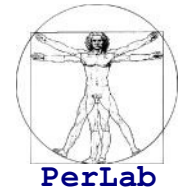
# Traffic-Air Pollution Correlation



- 2 monitoring stations
  - Managed by ARPA
- 3 more low-cost stations
  - UniPI-PisaMO project

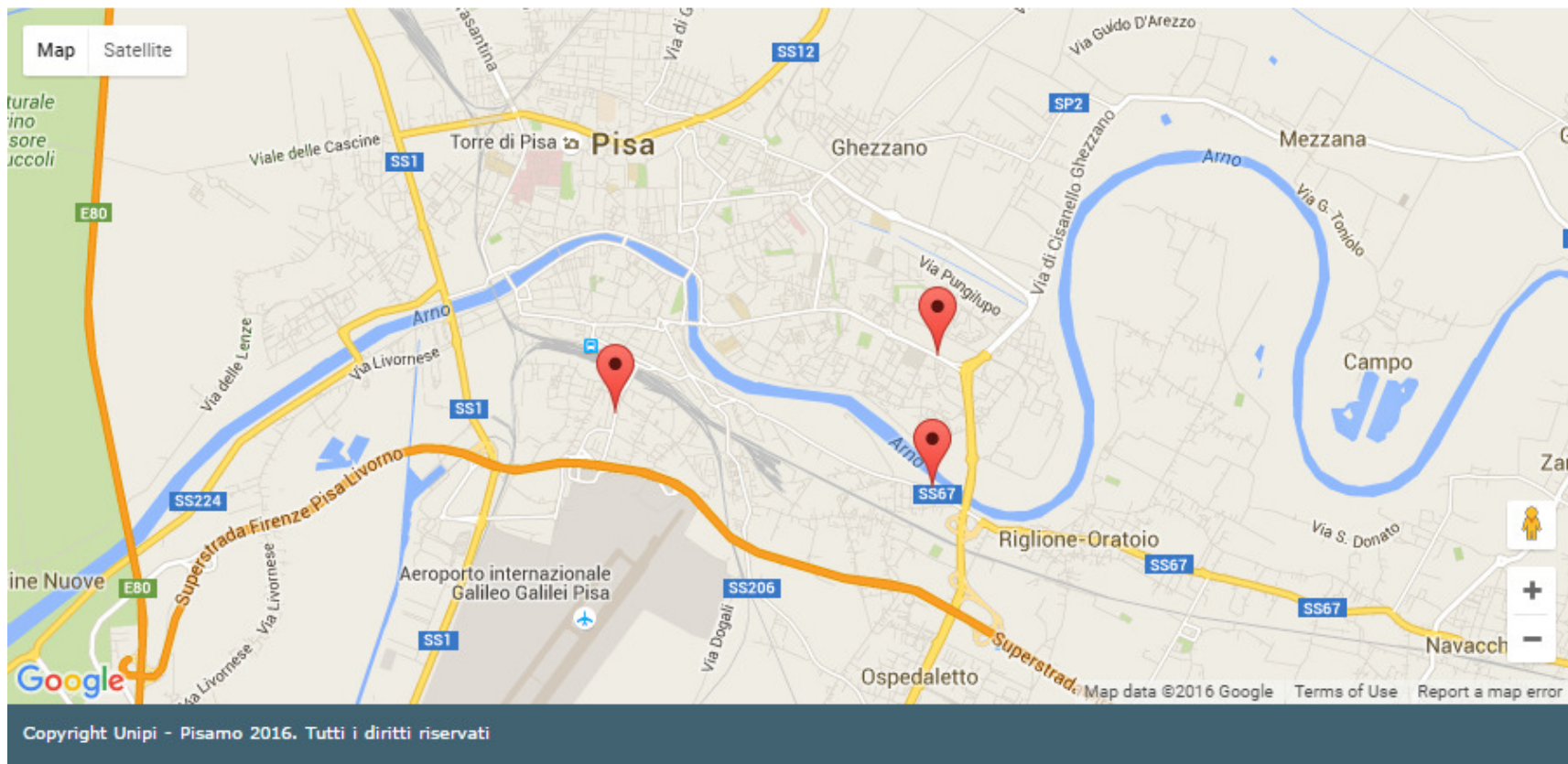


# Low-cost Stations

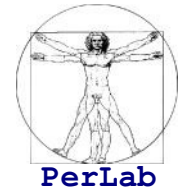


Home Sensors Map

Click on a marker for information on air quality at the selected point



# Low-cost Stations



[Home](#) [Sensors Map](#)

## Data from sensor 3 (, Pisa)

Look day (dd/mm/yyyy)    [Visualizza dati](#)

[Download CSV format data file](#)

[Open Graph:](#)

[Temperature](#) - [Humidity](#) - [Battery](#) - [CO](#) - [O3](#) - [NO2](#) - [SO2](#) [PM1](#) [PM2.5](#) [PM10](#)

Ora	Data	Temp (°C)	Humid (%)	Batt (%)	CO (PPM)	O3 (PPM)	NO2 (PPM)	SO2 (PPM)	PM1 (ug/m3)	PM2.5 (ug/m3)	PM10 (ug/m3)
19:02:33	04-07-2016	30.59	49	93	1.005	0	0.088	0	2.8898	9.8197	36.5529
18:47:17	04-07-2016	30.82	49	93	1.43	0	0.082	0	1.9368	5.3974	29.2854
18:32:03	04-07-2016	30.65	51	93	1.168	0	0.085	0	1.7572	4.5892	8.0421
18:16:40	04-07-2016	31.21	48	93	0.584	0.059	0.091	0	2.0674	6.1429	23.0078
18:01:17	04-07-2016	30.9	49	93	1.028	0	0.092	0	1.8631	4.3893	12.8938
17:45:58	04-07-2016	31.44	49	93	1.03	0	0.098	0	1.9582	4.131	6.2343
17:30:31	04-07-2016	31.39	49	93	0.776	0.056	0.094	0	2.8508	6.2902	8.7065
17:15:17	04-07-2016	31.21	48	93	0.909	0.043	0.079	0	2.1306	4.1025	4.9122
16:59:50	04-07-2016	31.23	47	93	0.796	0	0.087	0	2.1627	5.4366	24.1856