Citizens and cities facing new hazards and threats

30th November to 4th December 2020

SESSION 7 :

Smart resilient cities

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Consiglio Nazionale delle Ricerche

Université Gustave Eiffel

Outline

- Challenges of the Covid 19 pandemic in urban areas
- Necessity of a systematic approach for resilient urban areas
- The key factor of the integration
- Some examples of previous cases and the sustainability of the integrated approach
- Advances and new application fields enabled by the integration approach
- Conclusions

The challenges of COVID pandemic in urban areas

- **COVID 19 pandemic has now revolutionized completely our life and socio-economic relationships at individual and public level**

- **Urban areas and cities are trying to manage their immediate response to the COVID-19 pandemic and, at the same time, are rethinking to the planning and managing resources**

- **The concept of the inclusivity is crucial since the COVID pandemic has shown that the most vulnerable population is the one living at the poorly and densely populated areas**

- **It is necessary to ensure the continuity and reliability of essential services (transport, energy and water supply, waste disposal, etc.). This is a true challenge in urban areas characterized by a strong interconnection and interdependence among the various services and networks. This interdependence can be exploited to improve the response to the pandemic.**

- **It is necessary not only to protect vulnerable people from immediate threats but also to improve resilience for facing multi-risk scenarios**

The necessity of a systematic approach to the surveillance/monitoring of urban areas

- **To face the multi-risk scenarios**
- **To support the planning of the maintenance interventions of the critical infrastructure and services**
- **To mitigate and prevent the effects of the hazards through early warning capabilities**
- **To support the management of the crisis events**
- **To perform the quick damage assessment after crisis events**

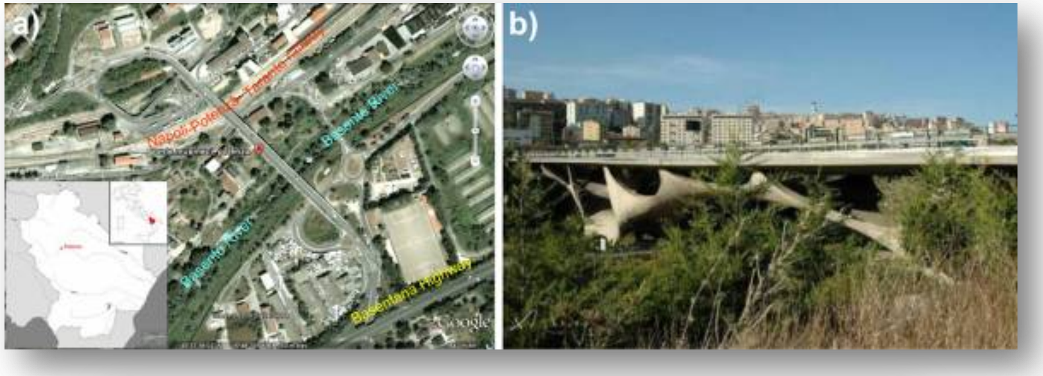
The key of the integration

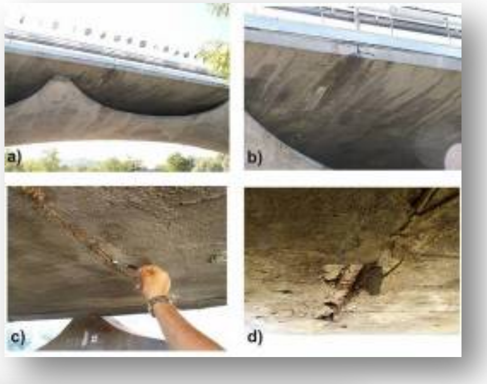
The resilience must be addressed under a holistic frame through:

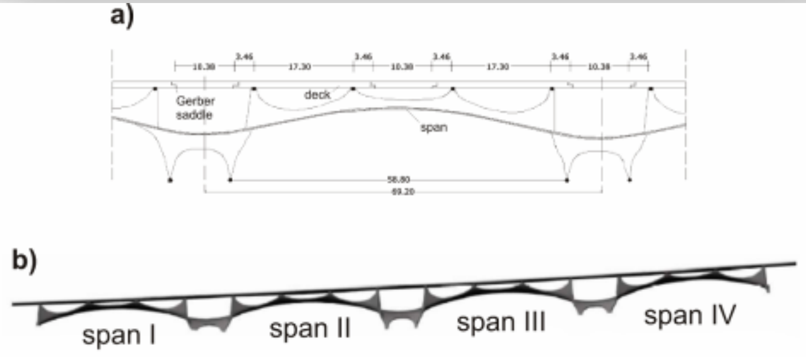
- **The capability to couple the monitoring of the infrastructure with the one of the embedding site**
- **The development of a monitoring platform able to integrate different kind of sensing/diagnostics technologies with Spatial Data infrastructure and ICT architectures**
- **The capability to assimilate "monitoring data" into civil engineering or mobility models with the end to assess the loss of performance of structure or transportation system. This is crucial to identify actions and strategies for an effective and economically sustainable management of the infrastructure**
- **The possibility to couple current monitoring with early warning and quick damage assessment capabilities, then to follow remedial solutions in crisis situations**
- **The use of AI and Big Data for behaviour prediction of the urban areas and embedding territory at the present status and in future risk scenarios (climatic, pandemic, hydrogeological, seismic…)**

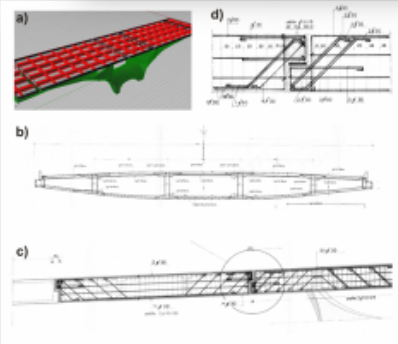
10 years ago…the experience of FP7 «ISTIMES» project (2009-2012)

Example of Integrated monitoring at Basento Viaduct



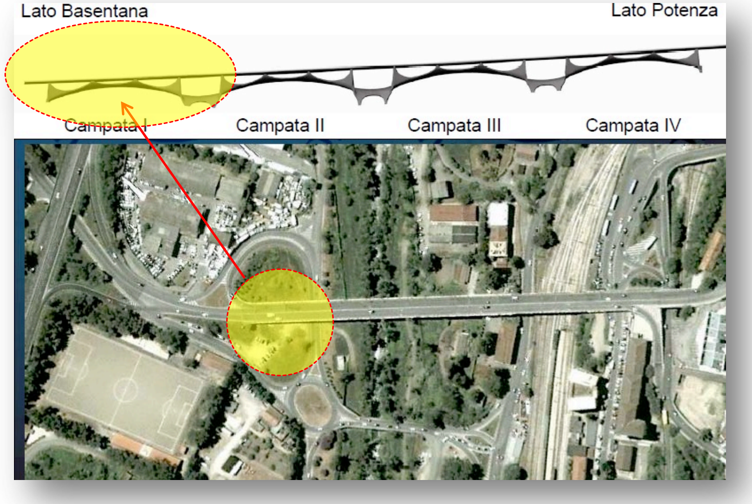


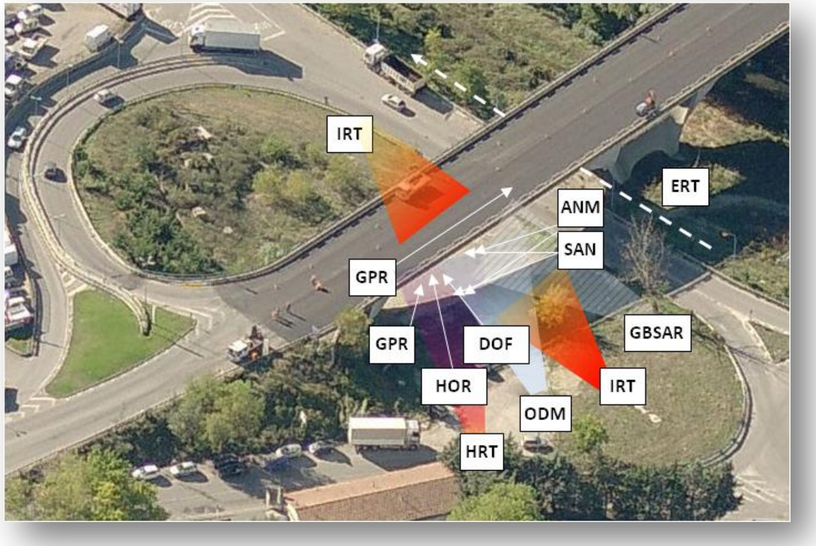




The bridge is an important way linking Potenza town to the Potenza-Sicignano highway and a valuable architectonic building of XX century designed by the italian civil engineer Sergio Musmeci between 1960 and 1970.

Sensing Technologies at Basento Viaduct



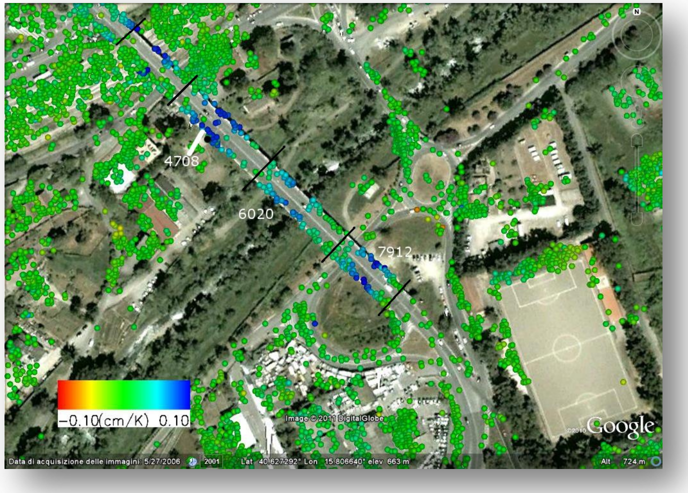


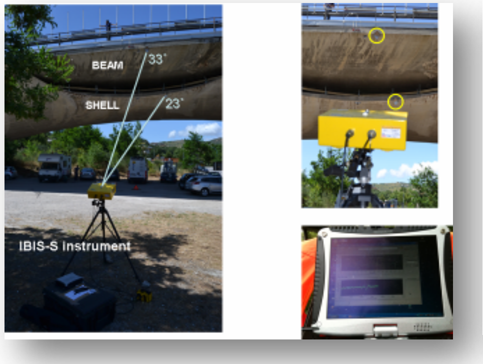
- **Electrical Resistivity Tomography (ERT)**
- **Ground Penetrating Radar (GPR)**
- **Mobile GPR**
- **RASCAN**
- **Fiber Optic Sensors (FOS)**
- **Synthetic Aperture Radar (SAR)**
- **Ground Based SAR (GB-SAR**

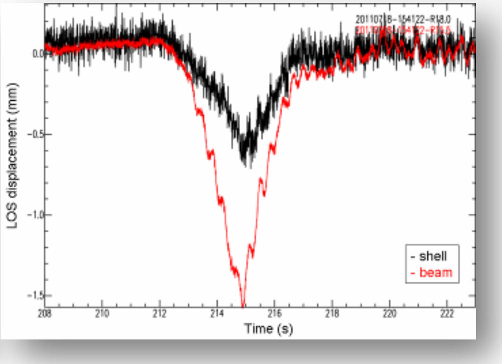
- **Cooled and Uncooled Infrared Termography (IRT)**
- **Optical displacement Monitoring (ODM)**
- **LASER SCANNER (A-LIDAR)**
- **Seismic micro-tremors measurements**
- **Accelerometric measurements**
- **Airborne surveys: laser scanner, digital camera, thermal camera and hyper-spectral sensors**

Sensing results at Basento Viaduct

SAR

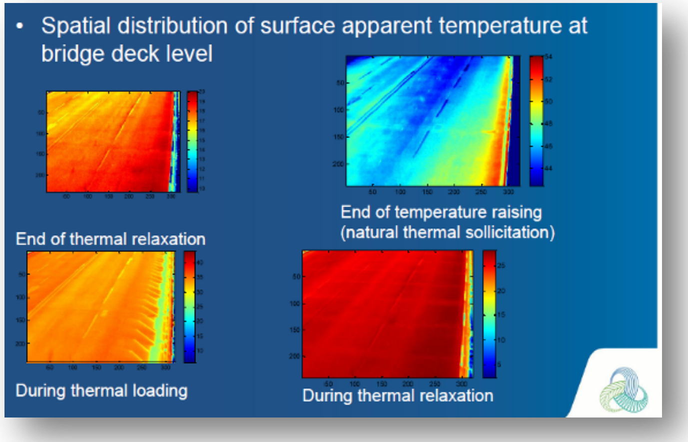






GB-SAR

IRT



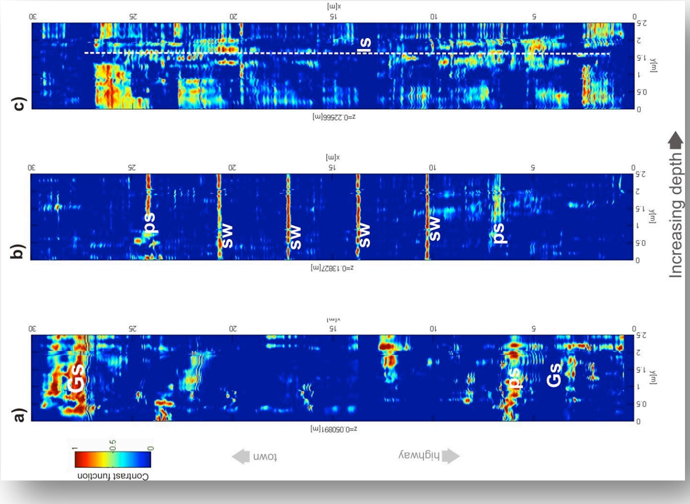
- Spatial distribution of surface apparent temperature at bridge deck level

End of thermal relaxation

End of temperature raising (natural thermal sollicitation)

During thermal loading

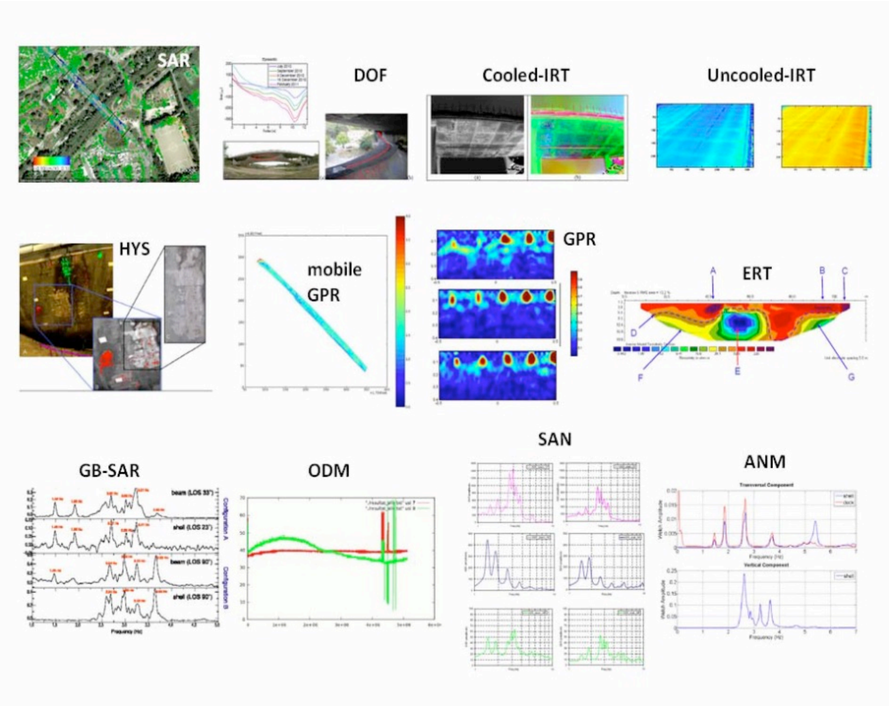
During thermal relaxation

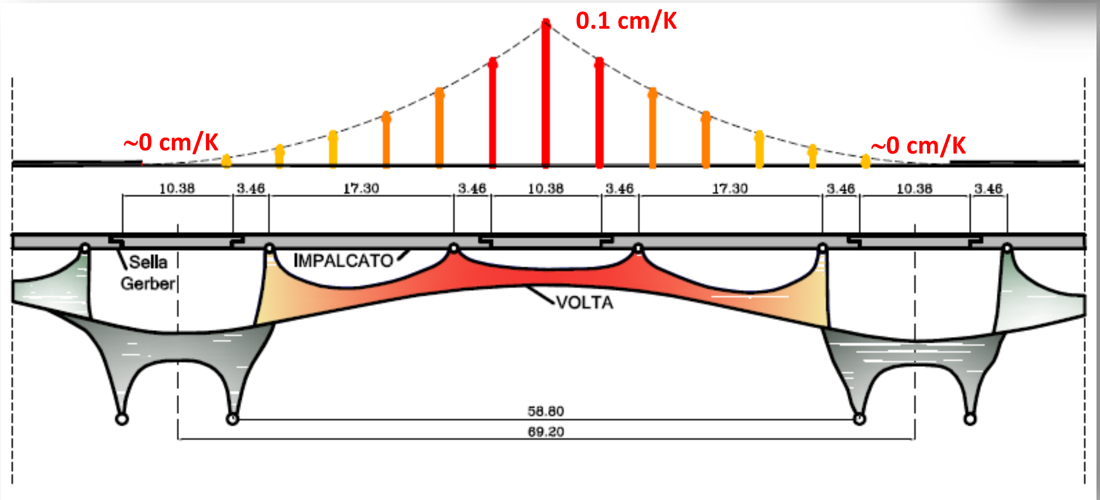


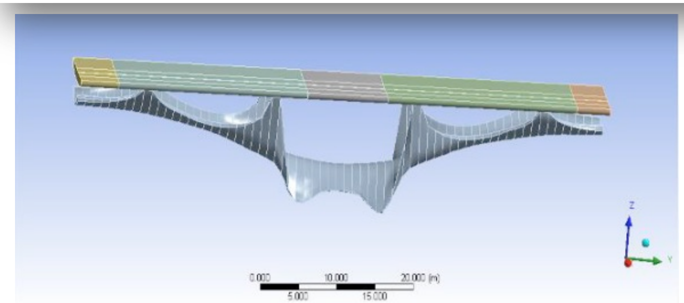
GPR

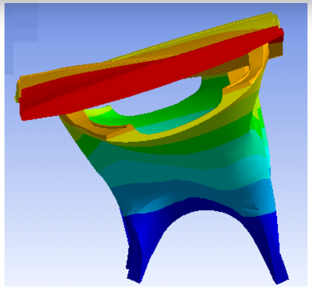
Francesco Soldovieri et al.

Link between sensing and civil engineering models









The sustainability of the integrated approach

….is ensured not only by the economic savings related to the prioritization and efficient planning of the maintenance interventions and the feeling of the most vulnerable population to be included in the social life.

but also by

a smart use of all the technological tools through the definition of operative protocols

⬇

Operational chains to point the choice of the technologies are developed on the basis of the specific scenario (structure, territory, risks,..) and more sophisticated sensing techniques are activated after that criticalities are detected by cheaper and easier to be deployed sensors

Example of operative protocol for a bridge monitoring

Level 0

The integration of the technologies allows to activate an almost entirely automated Long Term Monitoring and Early Warning strategy. This strategy is able to follow the life of an infrastructure continuously over time, by limiting at minimum the exploitation of personnel, just to periodic inspections, and traffic interruptions. Therefore, this level is characterized by the use of technologies that require an extremely simplified logistics (minimum personnel intervention). At this level, the interruption of the operation of the structure has almost zero probability.

Level 0 provides information about:
the deformation status of the structure and of the surrounding territory (SAR);
the frequencies of structural vibration and on their possible variation over time, this parameter is an indicator of the health of the structure (Accelerometers/GB-SAR);
the status of damage/deterioration of the surfaces (Infrared Thermography/Optical sensors) .

Example of operative protocol for a bridge monitoring

Level 1

Based on the info achieved by Level 0 or also on request, Level 1 can be activated. In this way, it is possible to deepen the information of Level 0, improving the spatial detail and knowledge of the structural elements. Level 1 is activated when Level 0 indicates the presence of criticality and is characterized by a more complex logistics. In few cases, the installation of accelerometers may require direct access to the structure with a consequent short traffic interruption. The use of sensors on mobile vehicles does not, however, require the interruption of traffic.

This level provides information on the modal behaviour of the structure and therefore is able to detect, quantify and possibly localize the damage on the structural elements. The use of mobile ground penetrating radar (mainly at deck) allows you to check the damage and characterize its type (oxidation of the reinforcement bars, change of the mechanical characteristics of the concrete, breakage of pre-stressing strands).

Example of operative protocol for a bridge monitoring

Level 2

Level 2 should be envisaged only in cases when high criticalities have been detected at the two above levels. It consists of a detailed analysis of the state of the infrastructure and its single structural elements. In this case, the logistical needs are significant and requirie the presence of staff and most likely the traffic interruption.

This level involves the use of technologies such as ground penetrating radar, electrical resistivity tomography, ultrasound to be operated with presence of the operators and able to make a detailed investigation of single elements of the structure coupled with reverse Civil Engineering.

The new frontiers in the monitoring

- **The improvement of technologies as Earth Observation, positioning and navigation, TLC, ICT (web sensors and web services, HPC, Big Data,embedded computing, IoT, IA) ➔ Move to integration strategies**
- **The development of new observational platform (mini and micro satellite constellations, fractionated missions, stratospheric platforms, drones, remotely piloted platforms) ➔ Move from silo to networked integrative platforms**
- **Building smart Digital Twins at territory scale ➔ Move towards next generation tools for resilience**

CLARA - CLoud plAtform and smart underground imaging for natural Risk Assessment

Sensor synergy for 3D multi-resolution, multi-scale, multi-sensing surface and subsurface imaging

CLARA Project
CLoud plAtform and smart underground imaging
for natural Risk Assessment

Remote sensing

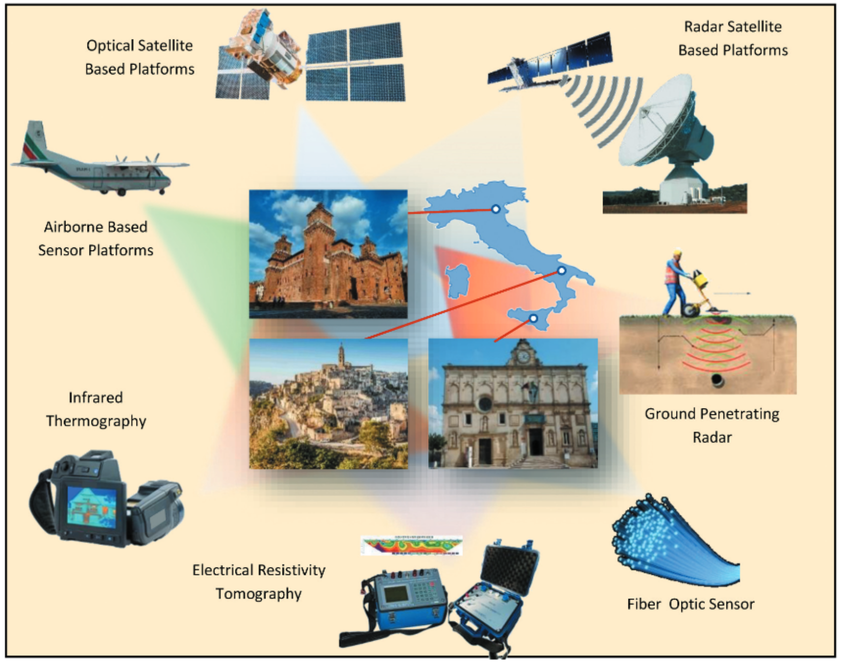
- Radar satellite technologies
- Optical satellite technologies
- Sensors on UAV, drones

In-situ geophysical tomography

- Seismic Tomography
- Electrical Tomography
- Microwave Tomography

Low-cost sensors and ICT tools

- MEMS sensors
- Accelerometric Sensor network
- Fiber optics
- Big Data, 5G, IOT



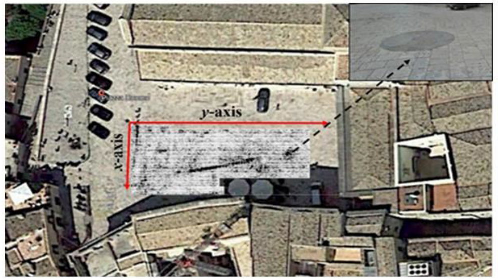
The necessities and the perspectives of the monitoring/surveillance systems for multi-risk scenarios of urban areas including COVID-19 pandemic

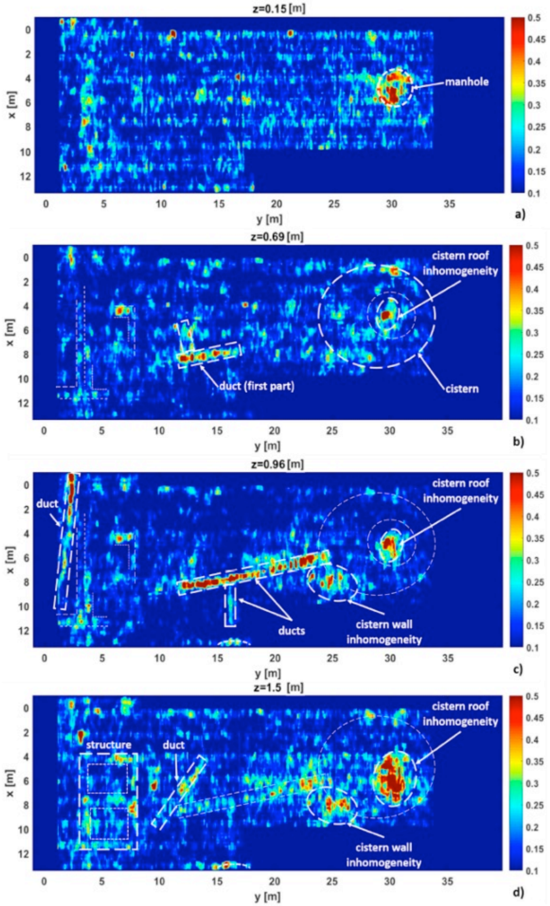
Special Issue on Remote Sensing of Environment: *Integration of Space and in-Situ techniques: a new Paradigm for the Monitoring and Surveillance.*

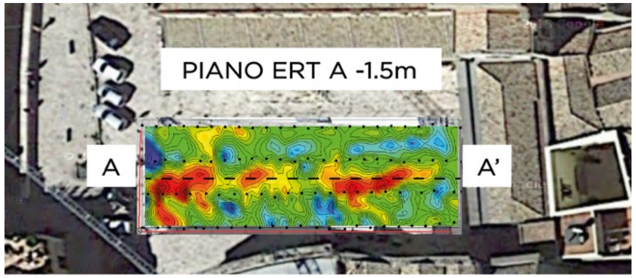
CLARA - CLoud plAtform and smart underground imaging for natural Risk Assessment

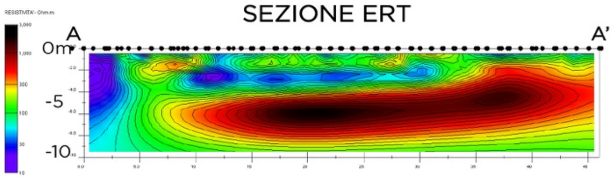
GPR and ERT tomographic imaging of subsurface in the Sassi historical center: Largo Duomo – Matera (Italy)

CLARA Project
CLoud plAtform and smart underground imaging
for natural Risk Assessment







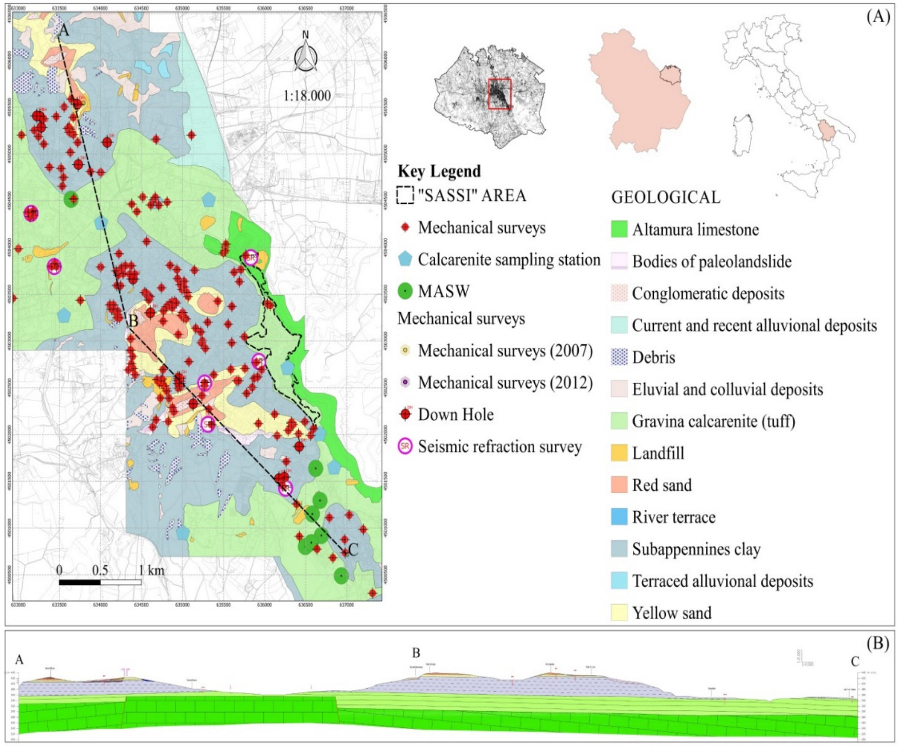


CLARA - CLoud plAtform and smart underground imaging for natural Risk Assessment

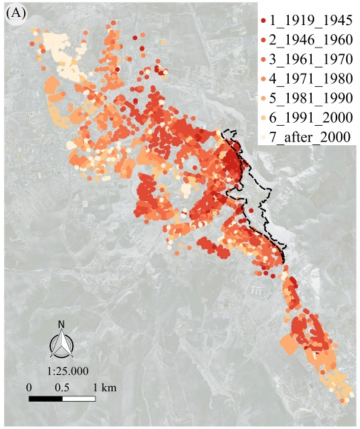
Non-invasive and multi-scale geophysical methods for mapping the resonance effect between soil and buildings in the city of Matera

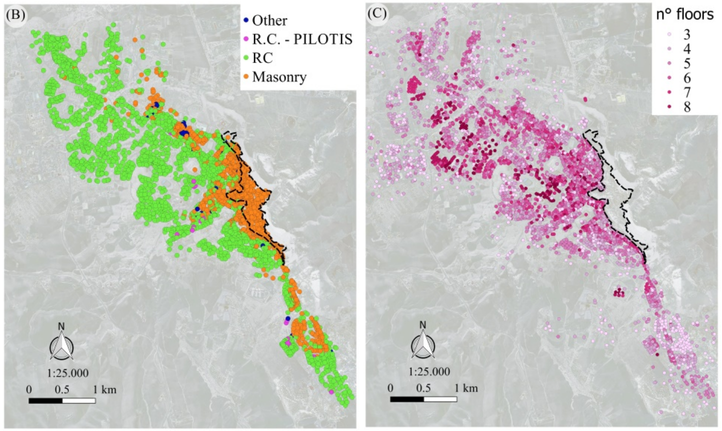
CLARA Project
CLoud plAtform and smart underground imaging
for natural Risk Assessment

Pre-existing geological and geophysical data



Characteristics of the 4049 selected buildings





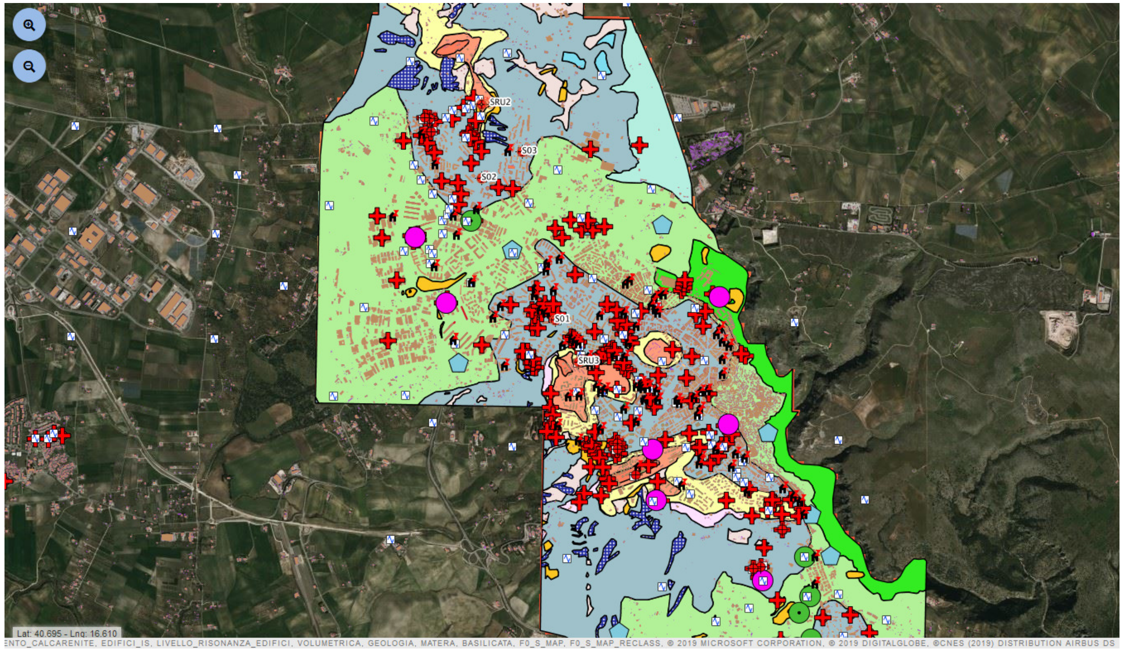
CLARA - CLoud plAtform and smart underground imaging for natural Risk Assessment

Open data approach for smart cities

CLARA Project
CLoud plAtform and smart underground imaging
for natural Risk Assessment

All the geological, geophysical and engineering data are organized with the GeoSDI platform. Full integration of data coming from the CLARA project with other public data and information.

- Geological maps
- Direct soundings and geotechnical information
- Seismic data (MASW, profiles)
- HVSR (soil and buildings)
- Engineering Information



https://smartcities-matera-clara.imaa.cnr.it/maplite/#/view/dashboard?mapID=300-50&x=16.610510746176377&y=40.662080927854&zoom=13&baseMap=GOOGLE_SATELLITE

Sensing as close as possible to citizens

Graphene-based humidity sensors on glass

Building monitoring via core-embedded carbon nanotube strain sensors on plastics

Water quality sensors on plastics and silicon with functionalized carbon nanotubes

Road monitoring via nanoparticle layers in asphalt

From the laboratories to the real world

Research labs,
clean rooms

**Effectiveness -
Paris la Défense**

Sense - City

Living lab

**New solutions
& Knowledge
for cities**

**How to implement solutions
in real world ?
What are the citizens needs
and feedbacks**

Analytics

Theme: PT100

Capteur: id_P1_1

Date debut: 2016-06-01 00:30

Date fin: 2016-10-30 00:30

PT100 – id_P1_1

Cliquez et faites glisser la zone de tracé pour effectuer un zoom avant

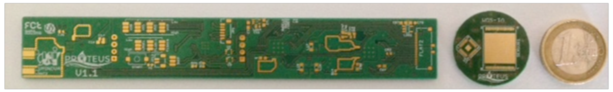
**Urban Sensor networks
performance test**

High spatial variability

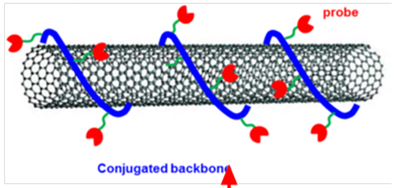
**Collect data , use model
and analyze the results**

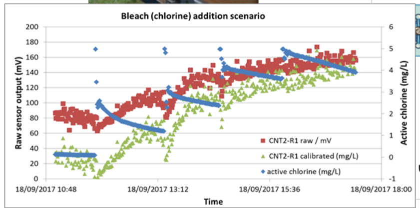
New sensors for Water monitoring

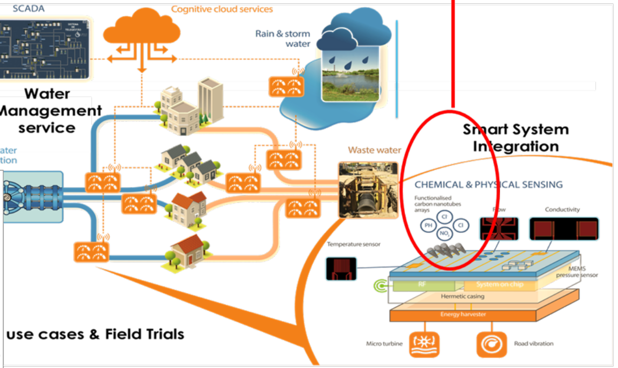
PROTEUS (H2020 Industrial Leadership), B. Lebental



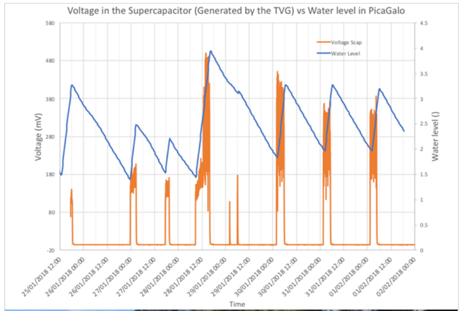
- Low cost sensor : 50x less
- 16 obs: pH, chlorine … on a single chip
  Sensitivity 10x better than SoA sensors
- validation : **Sense-City water network**
- **start-up maturing**

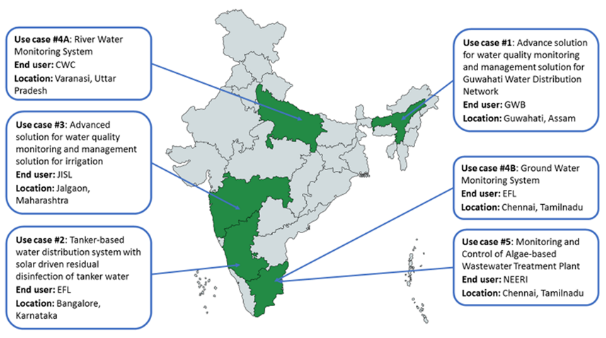






On site deployment :
Almada … India





Use case #4A: River Water Monitoring System
End user: CWC
Location: Varanasi, Uttar Pradesh

Use case #3: Advanced solution for water quality monitoring and management solution for irrigation
End user: JISL
Location: Jalgaon, Maharashtra

Use case #2: Tanker-based water distribution system with solar driven residual disinfection of tanker water
End user: EFL
Location: Bangalore, Karnataka

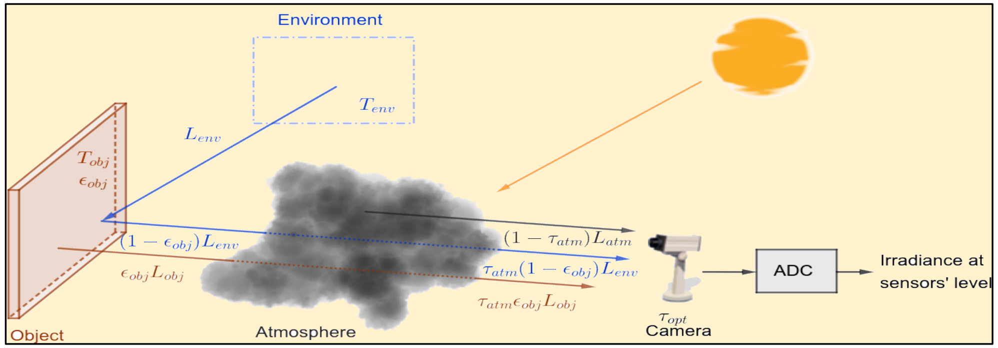
Use case #1: Advance solution for water quality monitoring and management solution for Guwahati Water Distribution Network
End user: GWB
Location: Guwahati, Assam

Use case #4B: Ground Water Monitoring System
End user: EFL
Location: Chennai, Tamilnadu

Use case #5: Monitoring and Control of Algae-based Wastewater Treatment Plant
End user: NEERI
Location: Chennai, Tamilnadu

Apparent surface temperature estimation for in-situ infrared thermal monitoring in outdoor conditions

Source errors for long-term *in-situ* thermal monitoring by IRT ➔ differ from airborne or satellite systems due to scale difference



The radiance $L_{total}^{i,j}$ at each pixel of the image can be derived from the extended simplified radiative transfer equation[1]:

$$\boxed{L_{total}^{i,j}} = \boxed{\epsilon_{obj}}\tau_{atm}\tau_{opt}L_{obj}^{i,j} + (1-\epsilon_{obj})\boxed{\tau_{atm}}\tau_{opt}(\boxed{L_{env}^{i,j}} + \boxed{L_{sun}^{i,j}}) + (1-\tau_{atm})\boxed{\tau_{opt}}\boxed{L_{atm}} + (1-\tau_{opt})\boxed{L_{opt}}$$

Image measurement value

Constant value for now derived from in-situ measurements or a priori knowledge

Derived from external temperature and relative humidity

Derived from sky temperature

Derived from local measurements or meteorological database

Constant value for now Can be derived from adhoc measurements

Derived from external temperature

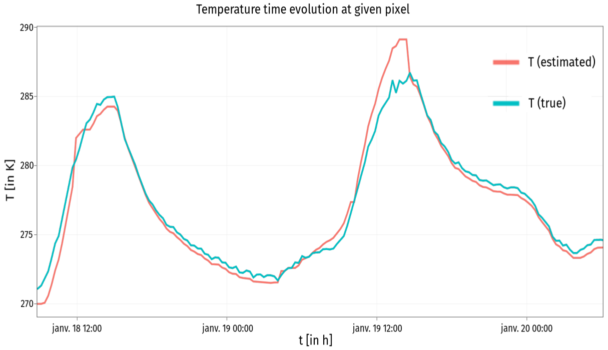
Constant value for now Can be derived from adhoc measurements

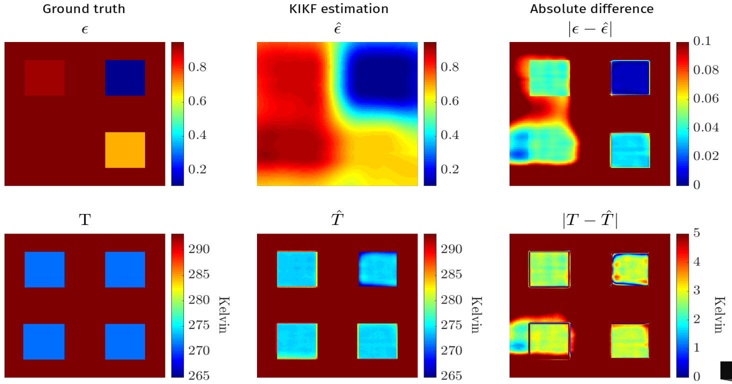
G. Gaussorgues, S. Chomet, Infrared Thermography, en, Springer Science & Business Media, Dec. 1993

Conjoint estimation of emissivity and temperature through a Bayesian model

Kriging-Based Interacting Particle Kalman Filter

KIPKF: Result of the temperature estimation through time





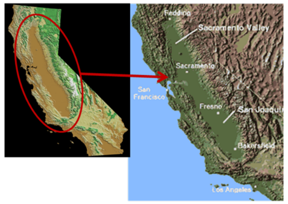
KIPKF: Simultaneous estimation result

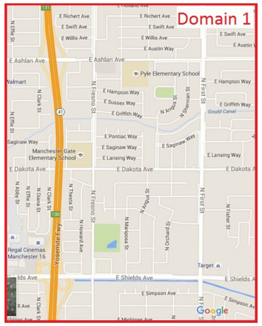
Toullier T., Dumoulin J. and Mevel L. « A Kriging-based Interacting Particle Kalman Filter for the simultaneous estimation of temperature and emissivity in Infrared imaging », IFAC 2020 – 21st IFAC World Congress, Jul 2020, Berlin, Germany.

Fast reconstruction of pollutant fields by PBDW

Air quality, Fresno, California

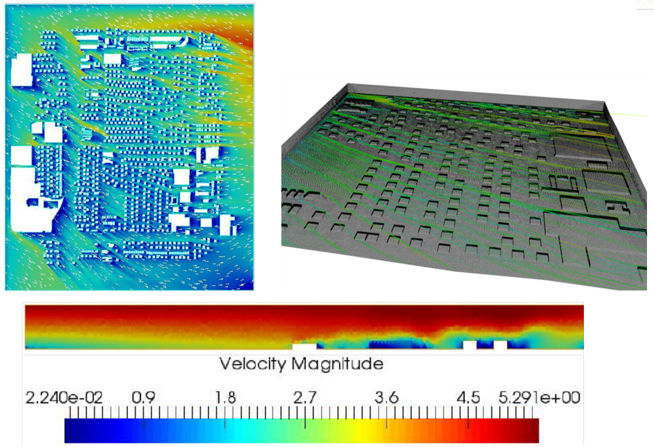
- San Joaquin Valley undergoes high pollution levels
- Fresno = 15 years of air pollution epidemiology studies



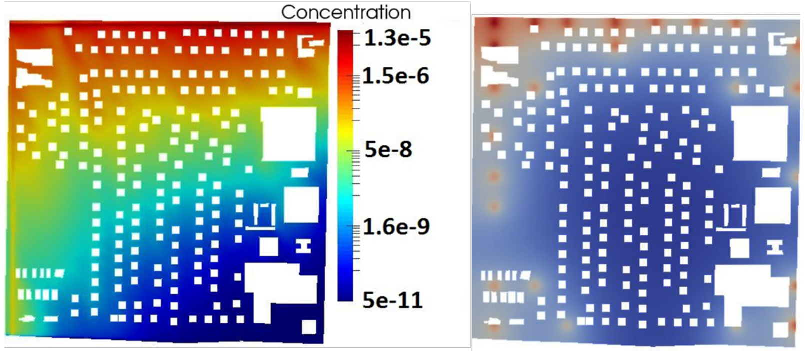


F Bourquin, R. Chakir, J. Hammond, Y. Maday
PBDW : Reduced order data assimilation for real-time monitoring of urban flows

Wind field and pollution map



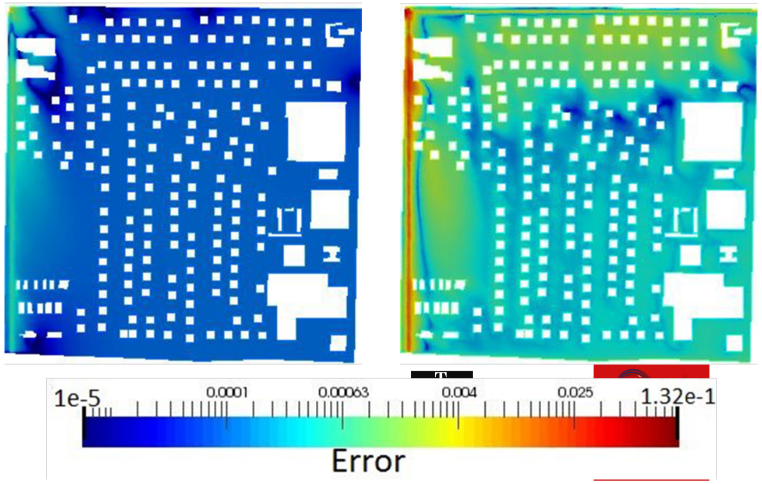
Left : concentration with 2 street pollution sources.
Right : Sensor locations chosen by a Greedy procedure



Relative PBDW approximation error

Perfect Model

Imperfect Model



Conclusions

- **Among lessons learned from Covid-19, a strong interconnection and interdependence among the various services and networks can be a risk factor or a useful tool to improve the response to the pandemic.**
- **The resilience as a whole, addressing urban areas, energy and transport infrastructures, TLC systems, health infrastructures in a unified and synergic manner**
- **Situational awareness and prevention as pillars of resilience**
- **The key role of monitoring in situational awareness and prevention**
- **The need to monitor both the state of the infrastructures, networks and system as well as the site where they are located**
- **The need to assimilate monitoring results into structural models in order to estimate performance losses and plan/prioritize interventions and extraordinary maintenance strategies**