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Utilisation of a Sensor Array for the Risk-Aware Navigation in Industrial Plants at Risk of NaTech Accidents

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Outline

- Motivation and objectives
- Case study industrial plant
- Sensor technologies
- Structural RIE module
- Environmental RIE module
- Implementation of the navigation software
- Summary and conclusions

ROSSINI
risk-aware navigation

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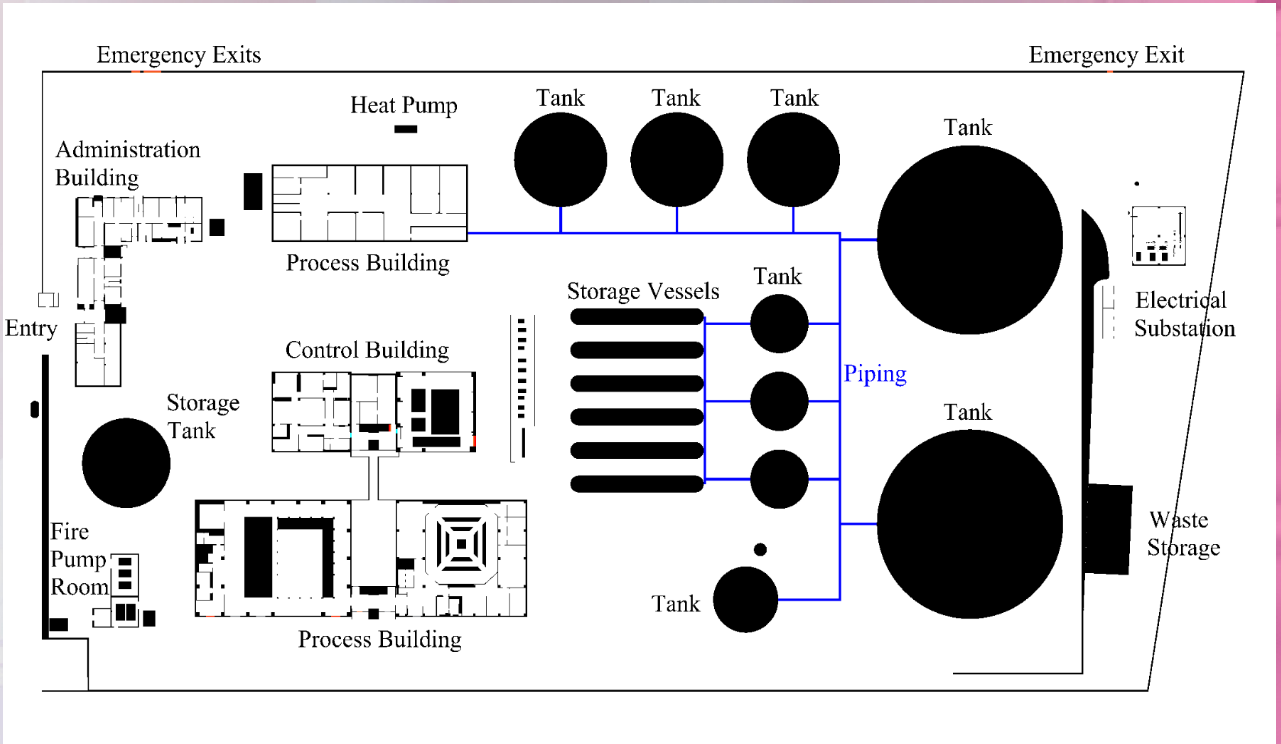
Motivation and Objectives

ROSSINI
risk-aware navigation

- Italy has high exposure to natural hazards triggering technological disasters (NaTech)
- ROSSINI project for risk-aware navigation of workers within a plant
- Objective is to design, implement and test a prototype system for risk-aware navigation to manage and mitigate seismic risk in industrial plants
- Risks computed following a seismic event
  - Industrial structures
  - Tanks
  - Piping systems etc.
- Consider possibility of toxic substances being released and diffused

Case Study Industrial Plant

- Several buildings comprising of components vulnerable to seismic shaking
- Building internal layouts
- Emergency exits



Sensor Technologies

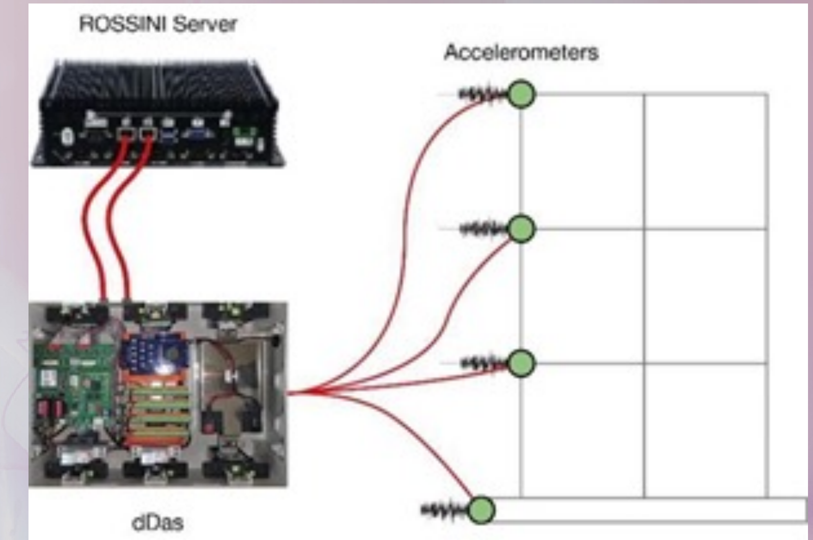
- ROSSINI platform integrates two risk identification and evaluation (RIE) methods
- Collection of input data for RIEs through different sensor technologies

Structural RIE

Environmental RIE

Sensor Technologies

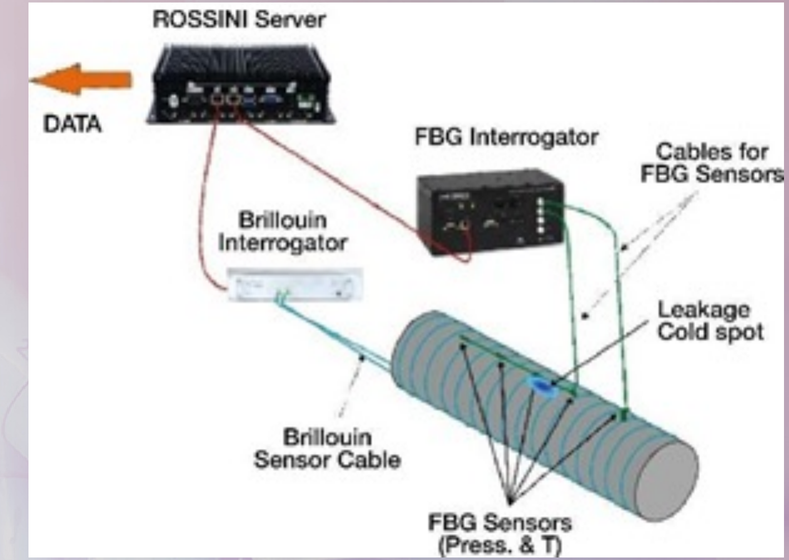
- ROSSINI platform integrates two risk identification and evaluation (RIE) methods
- Collection of input data for RIEs through different sensor technologies
  - **Micro-Electro-Mechanical-System (MEMS) accelerometers**



- ➢ Rapid evaluation of structural damage and provision of input data to structural RIE
- ➢ Accelerometer connected to a dynamic acquisition system to monitor accelerations
- ➢ Acquisition, filtering and processing

Sensor Technologies

- ROSSINI platform integrates two risk identification and evaluation (RIE) methods
- Collection of input data for RIEs through different sensor technologies
  - Micro-Electro-Mechanical-System (MEMS) accelerometers
  - **Fibre-optic sensors**



- ➢ To measure localised pressure and temperature variations
- ➢ Interrogation units connected to ROSSINI server for data collection and information sharing

Sensor Technologies

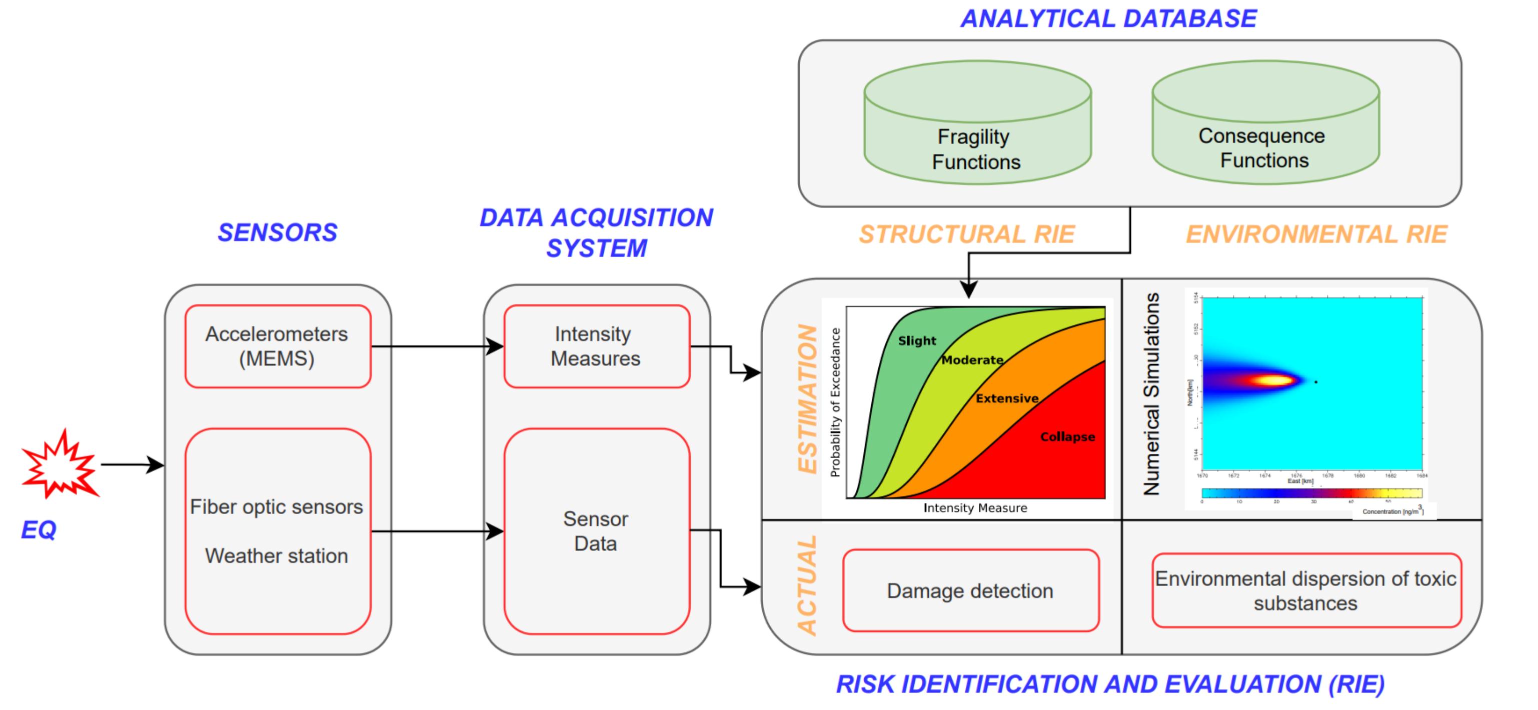
- ROSSINI platform integrates two risk identification and evaluation (RIE) methods
- Collection of input data for RIEs through different sensor technologies
  - Micro-Electro-Mechanical-System (MEMS) accelerometers
  - Fibre-optic sensors
  - **Weather station**

- ➢ Meteorological input data for environmental RIE
- ➢ Multiple sensors
  - ➢ Wind speed sensor
  - ➢ Thermogravimetric sensor
  - ➢ Wind direction sensor
  - ➢ Solar radiation sensor

❑ **Data Acquisition system**

Structural RIE

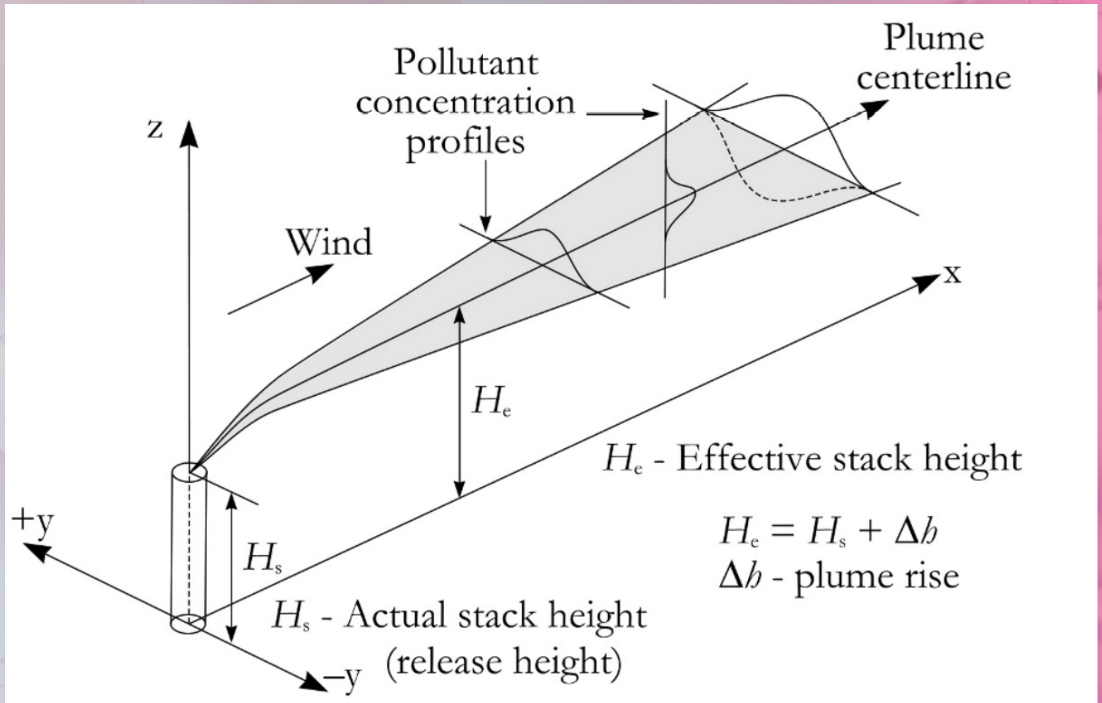
- Evaluation of structural damage via fragility curves
- Actual damage and leakage measurements using sensors
- Critical damage state (collapse) for structural components
- All damage states for non-structural components



- Non-structural failure (collapse)
- Release of toxic materials

Environmental RIE

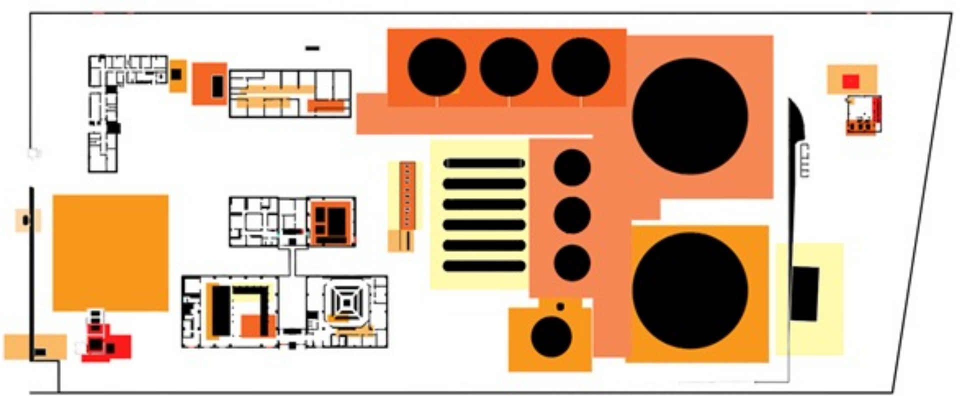
- Atmospheric dispersion models to simulate release of chemicals to predict air concentration levels of toxic materials
- Sensor data and meteorological measurements, simulations to estimate risk



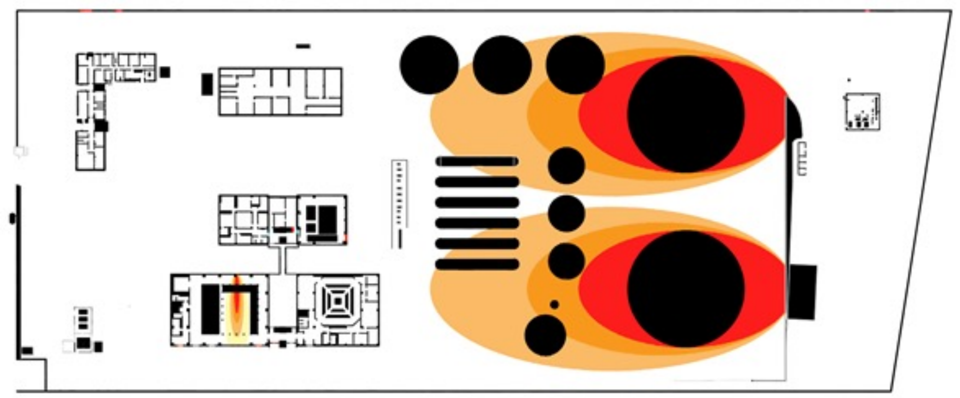
$$\dot{m}_{out} = A_t\omega = \begin{cases} A_tP\sqrt{\frac{kM}{RT}}\cdot\sqrt{\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \\ A_tP\sqrt{\left(\frac{2k}{k-1}\right)\frac{M}{RT}\left(\frac{P_B}{P}\right)^{\frac{2}{k}}\left[1-\left(\frac{P_B}{P}\right)^{\frac{k-1}{k}}\right]} \end{cases}$$

$$c(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left(\exp\left(\frac{-(z-h)^2}{2\sigma_z^2}\right)+\exp\left(\frac{-(z+h)^2}{2\sigma_z^2}\right)\right)$$

Combined RIE

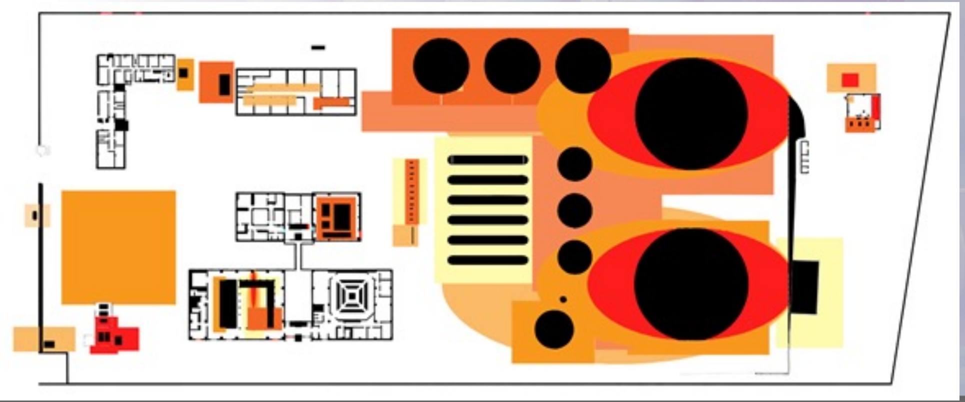


Structural Risk map

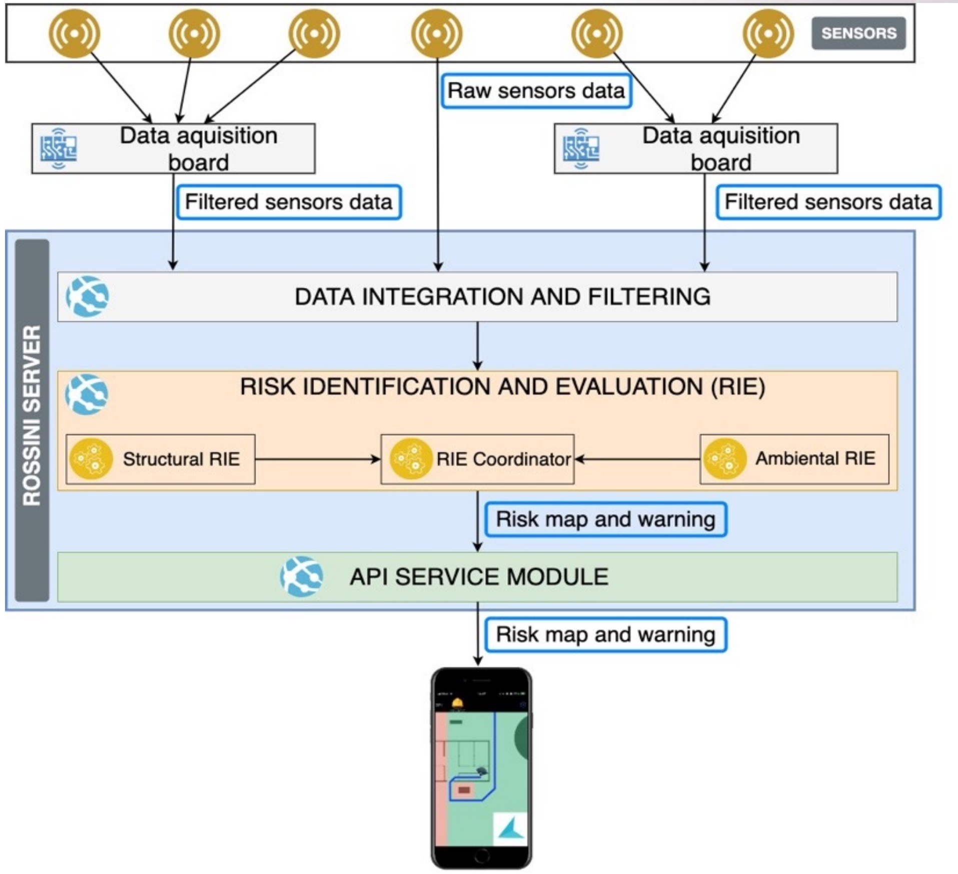


Environmental Risk map

Combined
Risk map



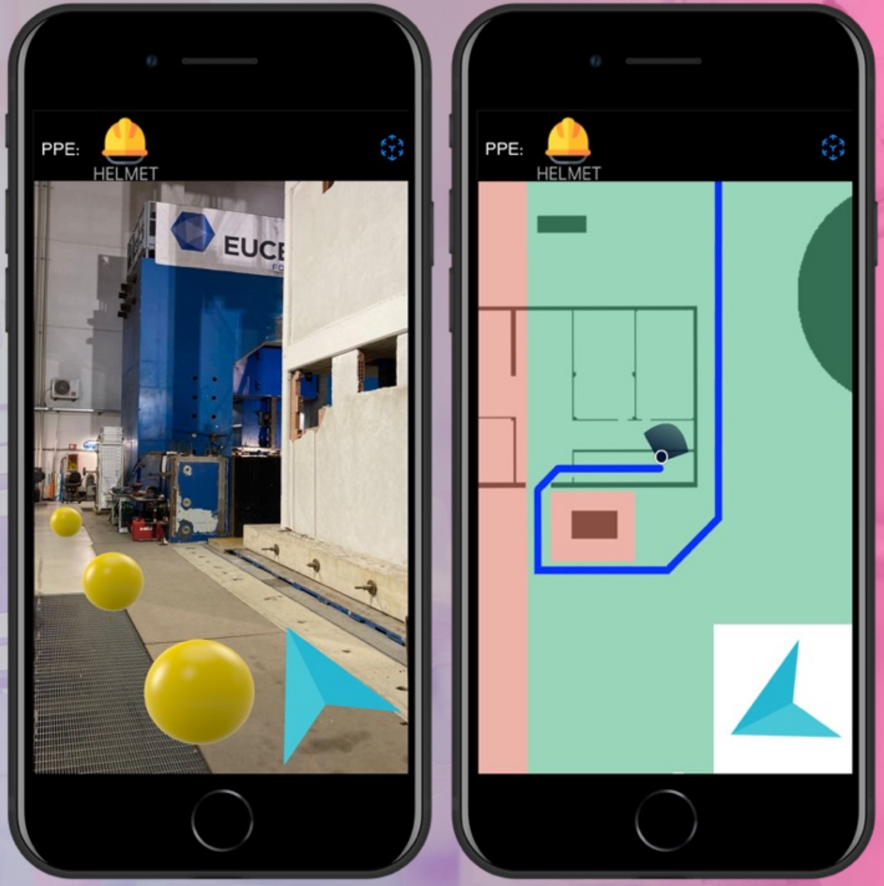
Implementation of the Navigation Software



- Mobile client running the application guiding the worker
- Set of sensors communicating with the ROSSINI server either directly or a through a data acquisition board
- ROSSINI server for raw data acquisition from sensors, integration and computation of combined risk map

Implementation of the Navigation Software

- Problems to resolve:
  - Reliable computation of precise user location
  - Guiding the user along the safest route
- **Positioning**
  - Hybrid solution based on a combination of indoor and outdoor positioning
  - Outdoor based on APIs (GNSS, WiFi)
  - Indoor ad-hoc based on visual markers
- **Navigation instructions**
  - Egocentric maps when user location is known with high precision
  - Allocentric maps when not known
  - Multi-modal approach combining visual information with audio and haptic information – sonification techniques



Summary and Conclusions

- Use of sensors to measure for damage measurements and estimations related to structural and environmental risk
- Use of various sensors as part of smart technologies to mitigate and manage risk
- ROSSINI system exploiting different sensors depending on the specific plant's needs and strategies
- Implementation within a mobile-based app
  - Using positioning and navigation techniques to guide the worker to safe extraction