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UTILIZATION OF A SENSOR ARRAY FOR THE RISK-AWARE NAVIGATION IN INDUSTRIAL PLANTS AT RISK OF NATECH ACCIDENTS

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ABSTRACT

This paper presents an overview of the ROSSINI project, illustrating its general objectives and how it places itself within the overall field of seismic risk-aware navigation systems. In particular, it describes the use of a sensor array for the integrated risk-aware navigation in industrial plants at risk of NaTech accidents. The integration of structural and environmental risks estimated and measured in different ways is presented as part of an integrated risk identification and evaluation (RIE) module. This module will be used along with a series of logic to combine and map the possible risks spatially within an industrial plant's layout. It is seen how this information can then be used to not only compute the safest path to safety for a worker located within such a plant but also how mobile communications can be used to aid and guide them in different scenarios. All of this stems from the use of a sensor array network in a relatively novel way within this particular context. The paper discusses the progress to date and presents the ongoing results of a pilot case study application of the system to an industrial plant facility in Italy.

Keywords: risk-aware; instrumentation; sensors; fragility; navigation; structural risk; environmental risk.

1. INTRODUCTION

Like many countries around the world, Italy is a country exposed to natural hazards triggering technological disasters (NaTech) that can cause fires, explosions and the release of toxic substances within industrial facilities. These disasters often pose grave concerns for the human lives directly in contact; namely, the plant workers. In this respect, IUSS Pavia, EUCENTRE and the University of Milan, in collaboration with the Italian National Institute for Insurance against Accidents at Work (INAIL), are collaborating to work on the design, implementation and testing of a prototype system for risk-aware navigation to manage and mitigate seismic risk in industrial plants at risk of NaTech accidents, entitled ROSSINI. For a given seismic shaking detected at an industrial plant, the system furnishes a real-time risk map for plant workers to use, and be navigated by, to safely egress via the safest (i.e., minimal risk) route automatically calculated by the system. Risks such as damage to piping systems, industrial structures, tanks, storage vessels and buildings, in general, are considered along with the possibility of toxic substances being released and diffused into the local atmosphere.

A key part of the ROSSINI system is the integration of risk estimates obtained from a classic fragility approach with a multi-sensor array. In the fragility approach, the probability of a given damage threshold, and subsequent consequence, can be estimated from a database of precompiled fragility and consequence functions and relayed to plant workers via the risk map. Furthermore, the provision of a series of smart sensors intends to directly measure and detect damage in key parts of the industrial facility. These measurements are anticipated to increase the efficiency and improve the reliability of the real-time risk estimates sent to plant workers via the ROSSINI system map.

This paper presents an overview of the ROSSINI project, illustrating its general objectives and how it places itself within the overall field of seismic risk-aware navigation systems. In particular, it describes the use of a sensor array for the integrated risk-aware navigation in industrial plants at risk of NaTech accidents. It discusses the progress to date and presents the ongoing results of a pilot case study application of the system to an industrial processing plant facility.

2. ROSSINI PROJECT

As stated previously, the ROSSINI project tackles the risk-aware navigation of industrial plant workers to avoid dangerous parts of a facility that may have collapsed or likely contain substances in the local environment that may be harmful to humans or may impede their vision and eventual egress from a building or structurally populated zone of the plant.

This paper follows the overall structure of the ROSSINI project and delves into the details surrounding the case study industrial plant development (Section 3) to implement and test the prototype. It describes the sensor technologies (Section 4) that will be used as part of the structural (Section 5) and environmental (Section 6) risk identification and evaluation (RIE) modules. Finally, the computational architecture developed to calculate the safest exit route and implement it within a mobile application is described in Section 7.

3. CASE STUDY INDUSTRIAL PLANT

For what concerns the project's implementation, a case study industrial plant layout was devised to be utilized within the ROSSINI platform for risk-aware navigation. Based on past studies analyzing the seismic risk of industrial plants [e.g., 1-2], several industrial plant processes were identified and considered within the case study development. While, within the studies, description and component typologies were described, the spatial description of the plant's elements and equipment often was not available. Critical to the navigation system developed in ROSSINI, the relative positions of the plant's components need to be identified to provide a navigable area for a hypothetical user. Additionally, it is important to identify the measure of components' damage, potential risk and likely path of potentially toxic material released into the local atmosphere. To this end, material regarding typical plant layouts and component types was examined for various industrial facilities located in Italy, which were largely petrochemical processing plants. Based on this available information from the literature with regards to industrial plants, a case study plant layout was devised (Figure 1).

The case study plant layout illustrated in Figure 1 consists of several buildings and arrangements of industrial facility structures, each of which comprises components vulnerable to seismic shaking. The case study plant comprises numerous components along with their relative position, building internal layouts and the emergency exits that will be used for the navigation system during prototype testing. These emergency exits have been hypothesized as an external environment (e.g., emergency meeting point) to which the worker must be navigated to in order to be no longer considered at risk of any potential harm within the industrial facility.

4. SENSOR TECHNOLOGIES

The ROSSINI platform integrates two different risk identification and evaluation methods: structural and environmental. The structural RIE (Section 5) is based on assessing structural damage of buildings and several plant components, such as pipelines, vessels and tanks. The environmental RIE (Section 6) instead results from estimating concentrations of chemicals in the entire industrial plant due to leakage from any plant component and simulating its spatial diffusion over time.

The collection of the input data for the two RIEs is carried out through the ROSSINI platform. This acquires and analyzes data from different sensor technologies, including Micro-Electro-Mechanical-System (MEMS) accelerometers, fibre-optic sensors (e.g., Fiber Bragg Grating, FBG, and distributed backscattering based) and a weather station, which are described below.

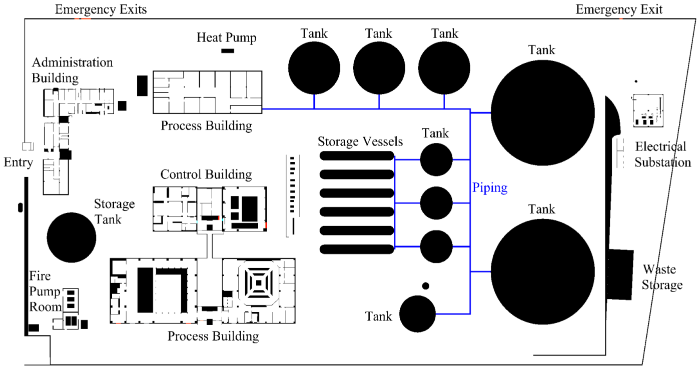


FIGURE 1: ILLUSTRATION OF THE CASE STUDY INDUSTRIAL PLANT LAYOUT AS PART OF THE ROSSINI PLATFORM, WHERE SEVERAL VULNERABLE COMPONENTS HAVE BEEN IDENTIFIED

4.1. Accelerometers (MEMS)

Triaxial MEMS accelerometers are used for rapidly evaluating possible structural damage and providing input data to the structural RIE (Section 5). Specifically, one accelerometer per floor is connected to a dynamic data acquisition system (dDas) to monitor dangerous peak accelerations and to periodically record environmental vibrations data useful for the identification of structural dynamics parameters (Figure 2). The dDas acquisition system comprises a standalone acquisition board capable of acquiring, filtering and processing up to 32 simultaneous analogue channels with 24bit precision analogue to digital converters (ADCs). This module features sample rates up to 1kHz for dynamic acquisitions or periods from 1sec to 24hrs for static acquisitions.

4.2. Fibre optic sensors

The use of fibre optic (FO) sensor technologies in engineering and industrial applications has been significantly increasing [e.g., 3-6]. This is largely due to the several advantages they hold with respect to traditional sensors, such as immunity to electromagnetic fields, high sensitivity, good embeddability, lightweight and durability, and the capability of covering wide areas.

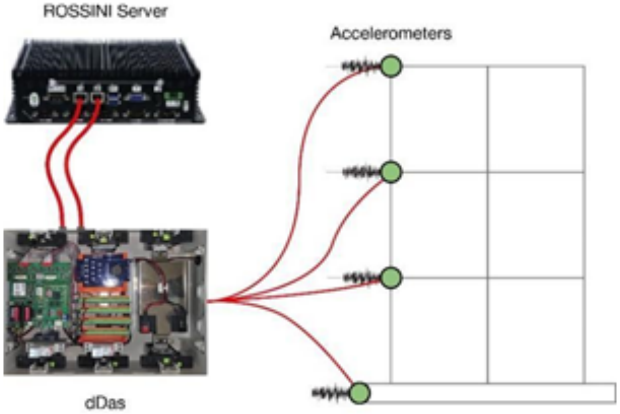


FIGURE 2: DETAILS OF THE SENSORS INSTALLED AT EACH FLOOR LEVEL AND HOW THEY CONNECT TO THE dDas ACQUISITION BOARD AND ROSSINI SERVER

In the Oil & Gas industry, FO sensors have found widespread application in down-well temperature measurements, the structural monitoring of oil rigs, and the detection and security monitoring of potential pipeline leakages. Given the notable potentialities of FO sensors, both Fiber Bragg Grating (FBG) and Brillouin backscattering distributed sensors are used in the ROSSINI Project to collect and provide emission data necessary for the environmental RIE (Section 6).

FBG sensors are point sensors available for a wide range of measurements, which can be used to build a large sensing network and which can be repeatedly queried at high frequency. Brillouin distributed systems exploit the full length of an optical fibre as a strain and temperature sensor and, consequently, they are quite suitable for pipeline monitoring.

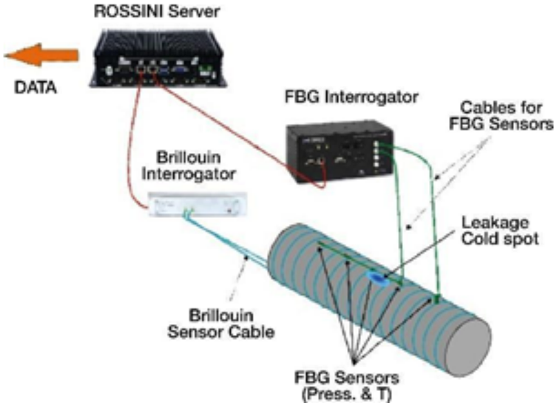


FIGURE 3: SCHEMATIC OF THE PROPOSED FO SYSTEM TO BE USED WITHIN THE ROSSINI PROJECT

Considering that gas leakages from pressurized vessels or pipes imply depressurization along with temperature drop, both pressure and temperature are monitored to detect possible gas releases into the environment. Specifically, FBG point sensors will be used to measure localized pressure and temperature variations at specific locations of the test vessel tested as part of the ROSSINI project. Distributed Brillouin sensors will also be employed for measuring temperature variations on a wide area of the surface of the same test vessel. Both types of sensors need to be connected to specific interrogation units through standard optical cables and connectors. The interrogation units are then connected to the ROSSINI server, capable of gathering data locally and sharing information throughout the online platform developed within the ROSSINI Project, which is depicted in Figure 3.

4.3. Weather station

A weather station is also used to provide meteorological input data for environmental RIE (Section 6). The weather station is equipped with a wind speed sensor, a thermogravimetric sensor, in addition to a wind direction and a solar radiation sensor, which are each shown in Figure 4.

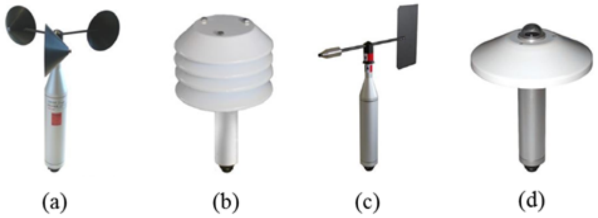


FIGURE 4: WEATHER STATION: a) WIND SPEED SENSOR; b) THERMOGRAVIMETRIC SENSOR; c) WIND DIRECTION SENSOR; d) SOLAR RADIATION SENSOR

4.4. Data acquisition system

The data acquisition system includes a set of several sensors installed in the environment, distributed processing units (called data acquisition board), and a data integration and filtering module running on the ROSSINI server in which robustness and redundancy have been considered of paramount importance during the design phase.

In the field of data acquisition, the novelty introduced by the ROSSINI system lays in the possibility to exploit different sensor technologies (i.e., MEMS accelerometers, fibre optic sensors and weather station) depending on the specific plant's needs and strategies agreed with the plant ownership.

The entire hardware architecture is designed to be robust and redundant to problems that can occur during earthquakes or serious damages to facilities which can compromise the safety and correct functionality of the monitoring and alerting system.

To ensure proper functioning in case of failure of the electrical system, the acquisition board is equipped with a battery that guarantees 12 hours of service and a solar panel to recharge it during the day. Also, the board electronics are suitably protected from accidental shocks or falling rubble by a rigid plastic box, allowing the system to operate in adverse conditions and harsh environments.

The acquisition board supports wired gigabit connection to the local area network and wireless 4G/LTE modem. The physical connection is the most reliable and efficient one available and it is used as a principal connection, whereas the wireless one is used as a fail-safe option. Although secondary, the wireless connection allows for sharing real-time data to the ROSSINI server with minimum latency.

5. STRUCTURAL RIE

The structural response is estimated using a combination of analytical expressions and sensoristic measurements. Figure 5 illustrates a general flowchart within the ROSSINI project demonstrating the flow of input arguments from various sensors, used to identify the seismic shaking through accelerograms and how they eventual pass to the RIE. The accelerometer measurements are processed on a data acquisition board into intensity measures (IMs) to be used with the fragility function database to provide ***estimates*** of risk associated with damageable components following the typical lognormal distribution function given as:

$$P[ds = DS|im] = \Phi\left(\frac{\ln im - \eta_{DS}}{\beta_{DS}}\right) \tag{1}$$

where η_{DS} is the median value and β_{DS} is the logarithmic standard deviation for a given damage state (DS). This evaluates the risk, or probability P, of the actual ds being realized for a given im value, which is obtained from the sensors.

Similarly, the sensors placed around the case study plant will detect ***actual*** damage and other types of leakage, which have been described previously. Both evaluation approaches, that is the estimation and actual measurement of notable damage with potential consequences depicted in Figure 5, form the structural part of the RIE Module.

To carry this out, Eq. (1) needs to be evaluated for each structural and non-structural component considered within the case study industrial plant, which was considered and mapped in Figure 1. This way, for a given level of shaking detected by the sensors, a real-time estimate of the probability can be obtained by the structural RIE. To enable this, descriptions of damage states and the subsequent consequences of being in a damaged state are provided via the analytical database depicted in Figure 5. This database can be compiled using detailed experimental testing information of the various components encountered, or via representative numerical models that capture the salient features of these structures' response and potential mechanisms, or via a literature review of similar components available in the literature.

In the ROSSINI project, peak ground acceleration (PGA) and spectral acceleration (SA) were used as IMs for characterizing the fragility functions associated with liquid tanks (Table 1). Similarly, fragility functions associated with process equipment and pipelines were adapted from available literature [7-8]. These consequence descriptors and the estimated level of risk they pose will allow for the assignment of indicators, for example wearing a mask within a specific grid. Additionally, each component is assigned to a specific location spatially within the map of the plant. Based on component location, an influence area is identified dependent on its vulnerability, where in case of failure, the influence area will be assigned a risk value and will feed the navigation system described in Section 7.

TABLE 1: DESCRIPTION OF DAMAGE STATES AND CONSEQUENCES OF LIQUID STORAGE TANKS SITUATED IN THE CASE STUDY PLANT.

Component type	Damage State	Consequence
Liquid storage tank	Excessive sloshing	Spillage of tank content/sinkage of floating roof
	Fracture /Yielding of Base Plate	Base plate failure/spillage of tank content (Local collapse)
	Yielding of structural shell	Panel joint failure as a result of excessive deformities in the structural shell
	Uplifting	Damage to nozzles, causing the release of a potentially harmful substance
	Sliding	Damage to nozzles, causing the release of a potentially harmful substance
	Elephant foot buckling of shell	Damage to structural shell
Multi-storey precast concrete structure	Extensive damage	Severe Damage to Structural Elements and In-Plane Damage of Horizontal and Vertical Panels
	Near-collapse	Unseating of Precast Beam; Loss of Beam-Column Connection
	Collapse	Complete Collapse of Structural System
Non-ductile infilled moment-resisting frame structure	Extensive damage	Severe Damage to Structural Elements and In-Plane Damage of Horizontal and Vertical Panels
	Near-collapse	30% of load bearing capacity attained with out-of-plane failure of infill panels
	Collapse	Complete Collapse of Structural System
Ductile bare MRF structure	Extensive damage	Severe damage to structural elements
	Near-collapse	30% of load bearing capacity attained
	Collapse	Complete Collapse of Structural System

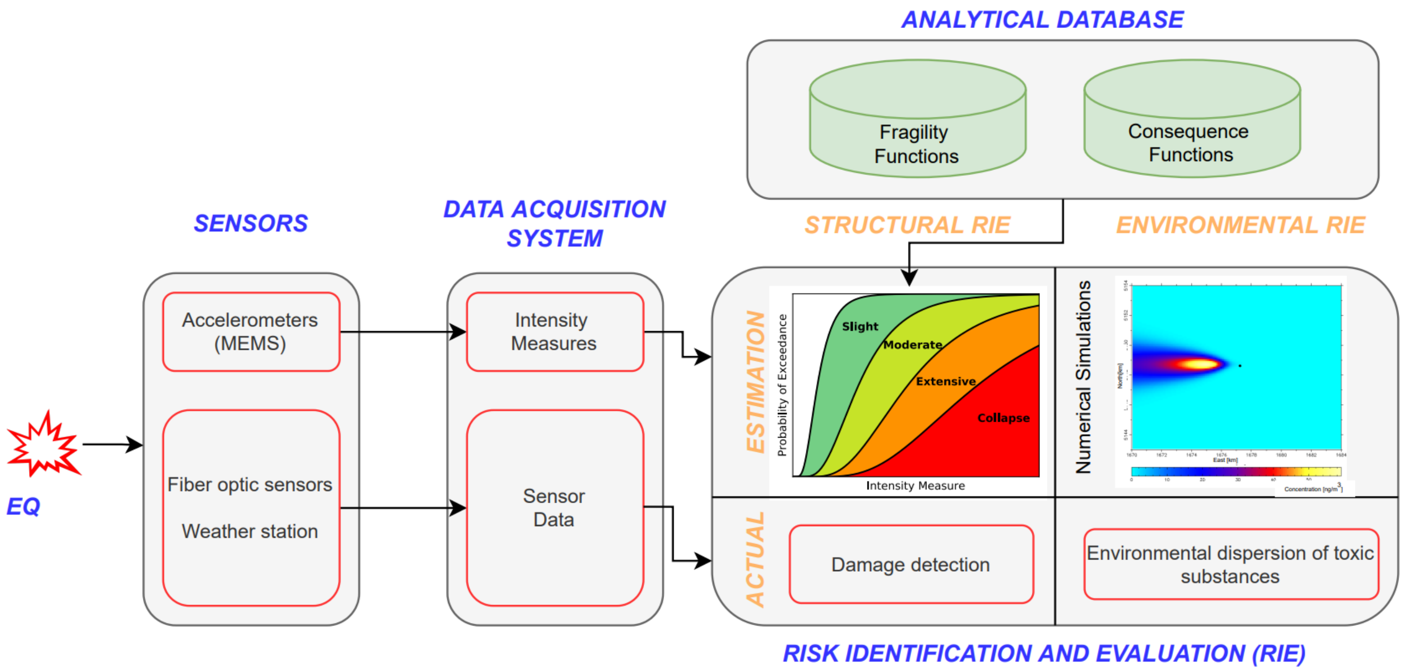


FIGURE 5: STRUCTURAL RESPONSE ESTIMATION USING FRAGILITY FUNCTION DATABASE COUPLED WITH SENSOR DATA.

Regarding seismic risk values necessary for the ROSSINI navigation system, only the critical damage state (i.e., collapse) of structural components is used in conjunction with the IM value to establish the probability or risk value between 0 and 1 based on the fragility function, illustrated in Figure 5. Here, 1 stands for non-traversable terrain, while 0 stands for fully traversable terrain. While only collapse of structural components can hinder free movement within the plant, non-structural components pertaining to various toxic material releases or leakages in addition to full collapse may be critical for navigating personnel within the plant to safely exit. The damage states and associated consequences of non-structural components such as liquid tanks as well as structural building typologies described in Table 1 need to be considered for the estimation of different risks. Those risks have various scales and are later combined with structural risk for total risk values associated with a spatially distributed map for navigation instructions.

6. ENVIRONMENTAL RIE

6.1. Calculation of environmental dispersion of released toxic substances

Atmospheric dispersion models are commonly employed for simulating the accidental continuous, transient, instantaneous or catastrophic release of chemicals from industrial plants, to predict air concentration levels of toxic substances in the surrounding environment.

The Gaussian plume model ISCST3 is selected among different dispersion models, following recommendations by the Environmental Protection Agency [9]. Concentration inside the plume is predicted by Gaussian statistics, with the centerline of the plume at the maximum of the Gaussian distribution and with the standard deviation of the Gaussian distribution an increasing function of time or downtime distance. During the release of concentrations, the ISCST3 model allows for describing the three-dimensional concentration field, produced by a point source under steady-state emission and meteorological conditions [10]:

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

where c is the pollutant concentration at a given location, Q is the source term, x is the downwind, y is the crosswind and z is the vertical direction and u is the wind speed at the height of the release h. The $\sigma_y=I_y x$ and $\sigma_z=I_z x$ deviations describe the crosswind and vertical mixing of the pollutant, where I_y and I_z are the turbulent wind speed fluctuations in the y and z directions, respectively. Dispersion values are determined by the magnitude of the turbulence in the atmosphere based on the Pasquill method [11].

Figure 6 sketches the spreading of pollutants from a source point. The concentration of pollution downwind from a source is treated as spreading outward from the centerline of the plume following a Gaussian distribution. The plume spreads both horizontally (y-direction) and vertically (z-direction).

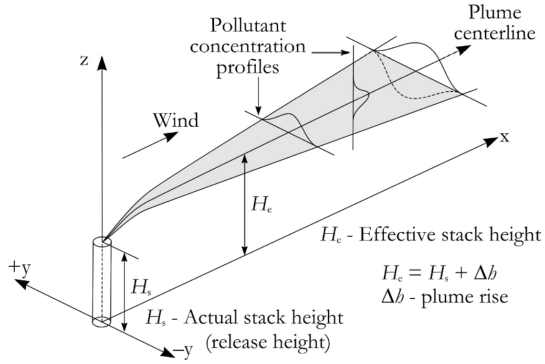


FIGURE 6: DIFFUSION OF POLLUTANTS FROM A POINT SOURCE [12]

6.2. Quantitative calculation of toxic releases based on data from sensors

The Gaussian plume model ISCST3, used for modelling of the environmental dispersion of toxic substances (Section 6.1), requires as input both emission (i.e., chemical name, release rate, height above the ground level of the release, geographical coordinates of the release point, temperature, physical state and exit velocity of the emitted substance) and meteorological (i.e., wind speed and direction, wind direction, air temperature, atmospheric stability Pasquill class and height of atmospheric mixing layer) data. Emission data are provided by both FBG and distributed backscattering-based sensors (Section 4.2), whereas meteorological data are given by an automatic meteorological station (Section 4.3).

For the quantitative calculation of toxic releases based on data from sensors, a simplified analytical model for the analysis of the discharge process of a pressurized vessel is also developed. The proposed model allows for estimating the instant mass outflow rate and also provides analytical relations allowing a continuous evaluation of pressure, temperature and density of the gas in the vessel. The simplified model assumes that the gas in the vessel is thermally and calorically perfect. The average velocity of the fluid in the tank is considered to be negligible with respect to the leakage velocity and contribution from gravitational potential energy is neglected. The leakage hole is modelled as a converging nozzle, with isentropic and quasi-unidimensional flow [13-14].

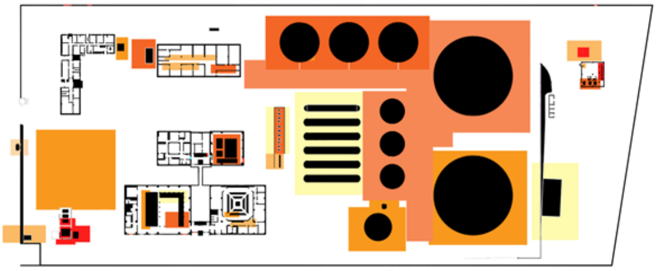
By modelling the opening of a leak as a converging nozzle, the mass outflow rate ($\dot{m}_{out}$) can be quantified via the following relations, depending on sonic (Eq. (3a)) or subsonic conditions (Eq. (3b)):

$$\dot{m}_{out} = A_t \rho \omega = \begin{cases} A_t P \sqrt{\frac{kM}{RT}} \cdot \sqrt{\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} & (3a) \\ A_t P \sqrt{\left(\frac{2k}{k-1}\right) \frac{M}{RT} \left(\frac{P_B}{P}\right)^{\frac{2}{k}} \left[1 - \left(\frac{P_B}{P}\right)^{\frac{k-1}{k}}\right]} & (3b) \end{cases}$$

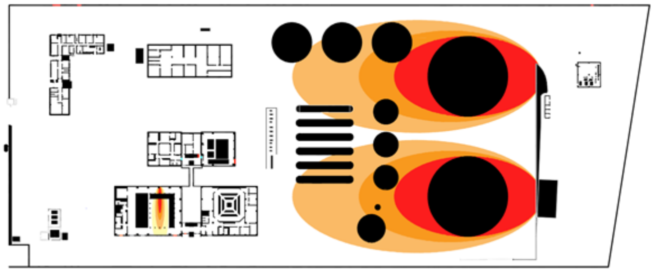
with A_t: leak area; ρ: gas density; ω: gas exit velocity; P and T: pressure and temperature of the gas in the vessel; P_B: ambient pressure; k: gas specific heat ratio; M: molar mass and R: gas constant.

The simplified analytical model also allows the discharge time assessment, which is essential for averaging the instant values of the outflow rate in the predetermined time window, in line with the input data required by the Gaussian models.

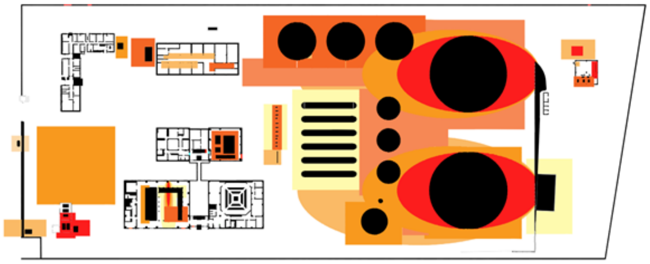
Sensor data from optical fibres are then coupled with meteorological measurements and numerical simulations for estimating concentrations of chemicals in the industrial plant and simulating their spatial diffusion over time, as required by the environmental part of RIE Module.



(a) Structural Risk Map



(b) Environmental Risks



(c) Combined Risk Maps

FIGURE 7: EXAMPLE OF RISK MAP DEVELOPMENT

6.3. Calculation and mapping of health risk values associated with potential exposure to released toxic substances

Health risk values, associated with the contamination levels in the environment (Sections 6.1 and 6.2), are mapped for identifying hot spot areas with higher risk for the workers' health. Structural and environmental risk maps are then superimposed to get a unified risk map (Figure 7), which provides clear guidance to minimize the overall health risk for the workers. The combined risk map is input to the navigation system, calculating the safest exit path from the industrial plant (Section 7).

7. IMPLEMENTATION

7.1. System Architecture

Figure 8 shows the system architecture from a navigation system implementation perspective. The main components are:

- A mobile client running the application to guide the worker during emergencies;
- The ROSSINI server, that acquires sensor data and uses it to compute the combined risk-map (Figure 7c) (i.e., a data structure representing the risk of transiting in each area of the plant); the risk-map is then transmitted to the client;
- A set of sensors that communicate with the ROSSINI server either directly or through a data acquisition board.

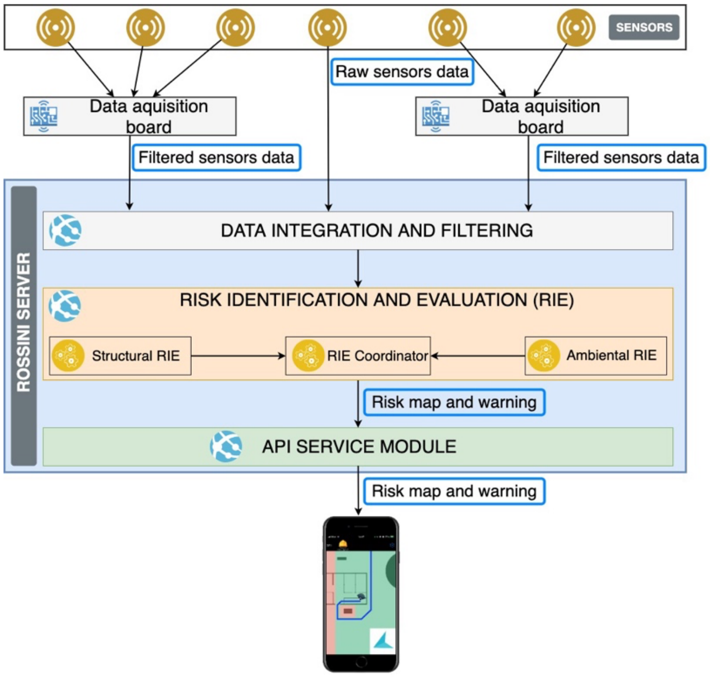


FIGURE 8: ROSSINI SYSTEM ARCHITECTURE

The ROSSINI server includes various modules, in particular:

- Data integration & filtering module: receives raw data from the sensors, integrates and filters them before providing them to the RIE module.
- RIE: this module integrates the structural and environmental RIEs (see Sections 5 and 6, respectively) combining the risk and creating the risk map.
- The API service module has the objective of providing the risk-map to the mobile client, also raising a warning when a potentially dangerous situation occurs.

7.2. Mobile app

Two main problems emerged in the analysis of the navigation app: 1) how to reliably compute the precise user location (which includes position and orientation); and 2) how to interact with the user to effectively guide them along the safest route.

After considering the state of the art, two solutions addressing these problems were devised:

- **Positioning**: a hybrid solution based on a combination of indoor and outdoor positioning techniques is used. While the outdoor solution uses the operating system APIs (which combine GNSS, WiFi and cellular positioning), the indoor positioning technique is an ad-hoc solution based on visual markers and visuo-inertial navigation. This solution has the advantage of not requiring external radio signals (which might be unavailable in emergency situations) and makes it possible to compute the user's orientation, in addition to their location. Also, this solution relies on augmented reality, which is implemented in stable and well-maintained libraries.
- **Navigation instructions**: a solution (see Figure 9) based on both allocentric and egocentric maps were designed. When the user's location is known with high precision, the system shows navigation information using an ecocentric map, also using augmented reality to better guide the user (see Figure 9, right). In case the user location is not known with high precision, the system shows the map with an egocentric approach (see Figure 9, left). In both cases, a multi-modal approach is adopted, combining visual information with audio and haptic information. In particular, the app adopts sonification techniques derived from the literature in the field of assistive technologies for people with visual impairments [15-16].

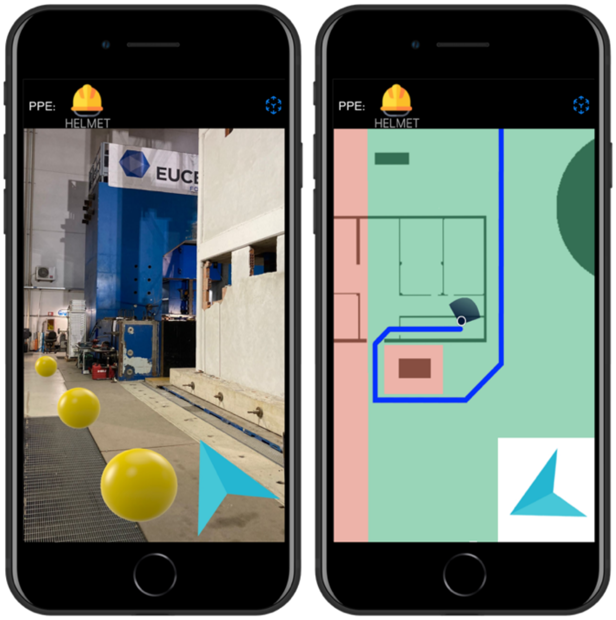


FIGURE 9: ROSSINI mobile Client. left: egocentric navigation; right: allocentric navigation.

The risk-aware route is computed on the client starting from two data structures: the risk-map (see above) and the *routes-graph*. The latter is a directed graph that represents all the walkable paths; this graph models the area into discrete cells and considers physical characteristics of the environment, like the walls and the emergency door (that can be traversed in one direction only). Starting from an area planimetry, an external app (i.e., not mobile) discretizes the space into cells and creates a node for each cell as well as the connections between nodes (e.g., two adjacent nodes are connected if there is not a wall between them). Figure 10 shows an example: black pixels represent walls, while the green arrows start from the centre of a cell and indicate which adjacent cells are connected. Red segments represent emergency doors that can be traversed in one direction only, while grey segments represent doors that can be traversed in both directions. This graph is then serialized as a file and transferred to the mobile device, where it is loaded when the app runs.

When the mobile app runs, it receives a new risk map as soon as it is available on the server. Once a risk map is received, the mobile app updates the weight of nodes in the routes-graph (e.g., if an area in the risk-map has a high risk, the nodes in the *routes-graph* contained in that area are updated to have a high weight). Then, using an adaptation of the A* algorithm the best route is computed from the current user position to each safe area and eventually the best route among them is selected. With "best route" we intend the route that minimizes the maximum weight, which is different to the typical implementation of A*, where the aim is to minimize the sum of the weight along the route.

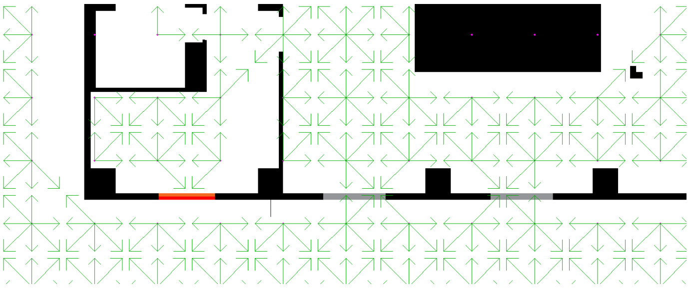


FIGURE 10: Example of the area discretized into cells and their connections.

8. SUMMARY AND CONCLUSION

This paper has presented an overview of the ROSSINI project and how it is being implemented within the context of risk-aware navigation for industrial plant workers exposed to harm during seismic events. The case study industrial plant used for the project was described in addition to the process of estimating both structural and environmental risks within it. It was seen how the structural risks may be estimated probabilistically from libraries of existing fragility functions to give an idea of the potential damage and associated risk for the workers, in addition to actual measurements taken real-time from a series of sensors located on pertinent structures. Similarly, the environmental risks can be computed by coupling sufficient background theory on the diffusion of harmful substances with the sensor array that can detect leakages and other such incidents.

The sensor technologies used in the project were described in detail to illustrate how such technology can be integrated as part of smart technologies to mitigate and manage risk in these scenarios. In terms of data acquisition, it was seen how the ROSSINI system introduces a novel way to exploit different sensor technologies (i.e., MEMS accelerometers, fibre optic sensors and weather station) depending on the specific plant's needs and strategies in place.

Lastly, and perhaps most critically for what concerns the objectives of the ROSSINI project, the implementation of this within a mobile-based app was described. The architecture under which the system operates was described followed by the introduction of two novel solutions to resolve potential issues regarding the location of a user within a system and the interaction with the user while guiding them along the safest route out of the plant.

To conclude, this paper presents an overview of the ROSSINI project, its objectives and implementation. Following these developments currently underway, the system will be tested and demonstrated in a simulated environment in the near future. This will be to illustrate the capabilities both in terms of the integration of a diverse sensor array in this context via an experiment on an industrial sub-assembly at the EUCENTRE shaking table facilities, coupled with a live demonstration of the mobile app to safely navigate around a fictitious risk map in real-time with various types of scenarios.

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