Emergency navigation assistance for industrial plants workers subject to situational impairment

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This contribution reports our ongoing effort in the development of the ROSSINI system, which looks to address emergency situations in industrial plants. The user interaction design of ROSSINI described in this paper takes into account the fact that the user can be subject to situational impairment (*e.g.*, limited sight). As such, it is envisioned that existing solutions designed for people with disabilities can be adopted and extended for this purpose.

CCS Concepts: • **Human-centered computing → Accessibility technologies**; **Accessibility systems and tools**; **Accessibility design and evaluation methods**.

Additional Key Words and Phrases: Situational impairment, navigation, emergency, sonification, NaTech, risk mitigation.

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1 INTRODUCTION

The term *NaTech* refers to natural hazards that trigger technological disasters. These events are characterised by the high potential for structural and non-structural element damage and collapse, in addition to the release of toxic materials into the local environment. These risks therefore give rise to a situation where the risk of casualty and serious illness to plant workers needs to be efficiently managed and mitigated via the provision of navigation assistance in order to exit the plant safely.

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This contribution reports our current effort in the ROSSINI project, aimed at developing a prototype system to mitigate the effects of *NaTech* events in industrial plants though a risk-aware navigation system. The ROSSINI system can help mitigate the effects of a *NaTech* event in two ways: first, it can support the employees to safely evacuate from the plant; second, it can guide an employee along a safe route to take active actions to limit the NaTech event (*e.g.*, turning a valve off). In a nutshell, the system will monitor the status of an industrial plant through a sensor network which provides data to a *risk models*. In case of emergency (*e.g.*, earthquake), the risk models estimate the likelihood of structural and non-structural component collapses in the plant, in addition to the likelihood and amount of release along with the location and concentration levels of potentially hazardous and toxic substances. These risk models outputs are used to determine how dangerous it is for a worker to transit certain areas, and is in turn used to identify and indicate the safest routes for the employees.

2 EXAMPLE SCENARIO

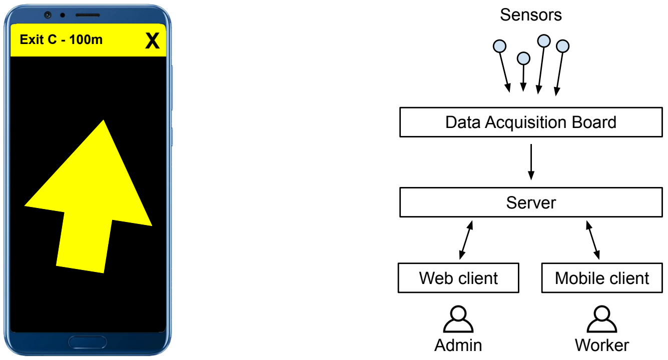
It is a normal working day (*i.e.*, non-emergency situation) the plant comprises dozens of workers positioned in various offices/work stations and random locations of the plant depending on that day's tasks. At a certain point, a powerful earthquake occurs and begins to shake the plants structural (*e.g.*, storage structures, office buildings) and non-structural (*e.g.*, storage tanks, silos, pipe racks) elements. Each worker's smartphone begins vibrating and shows the safest route to evacuate the plant based on their respective locations within the plant. The workers visually follow the directions provided by the app. However, after walking for a few metres, some workers in one part of the plant are unable to clearly distinguish the visual instructions due to thick smoke. The app also instructs the workers with audio and haptic (vibration) instructions, which the workers have learned to interpret during the training. With these simple and clear instructions, each worker can safely evacuate the plant.

3 USER INTERACTION DESIGN

In an emergency situation, the ROSSINI app guides the worker along a safe route towards a secure position. One possible solution to guide the worker can be based on a allocentric visualization, for example a bird's-eye view of the map area with a clearly-marked path to follow. Audio and haptic feedback can be used to inform the workers that they are on the wrong path. With this solution the mobile device must be aware of the worker's position (*i.e.*, GNSS could be sufficiently precise in an outdoor plant).

One limitation of the allocentric solution is that worker can be subject to *situational impairment* [3]. For example, the worker can have limited sight, hand mobility (*e.g.*, due to protective gloves), or hearing (*e.g.*, due to alarm sirens). In this condition, similar to what happens to people with visual impairments, it can be difficult for the workers to convert the allocentric representation into the egocentric information needed to navigate. For example the workers may have difficulties in correlating navigation instructions shown on the map with information acquired from the environment (*e.g.*, by sight). Thus, an alternative approach is to provide egocentric navigation instructions, *e.g.*, an arrow indicating the direction to follow, as shown in Figure 1(a). This approach requires the application to be aware of the worker's position and orientation with high accuracy. It is possible to collect this information using state of the art solution, however it is currently unclear to us how robust the resulting system could be. For example, it is unclear how visual-based solutions (vision can help computing the worker's orientation) are robust in case of thick smoke [2].

The information graphically shown on the interface depicted in Figure 1(a) can also be conveyed with audio-haptic feedback. This requires to adopt and possibly extend the existing techniques proposed in the literature for people with visual impairments (*e.g.*, [1]). In this situation, the main differences are that: (i) the worker would use the solution



(a) Mobile app interface (b) Architecture

Fig. 1. ROSSINI: mobile app interface and architecture.

sporadically (hence it should be easy to remember), (ii) the audio should be distinguishable also in the presence of other background noise (*e.g.*, alarm sirens), and (iii) the perception of vibration should be ensured even when the worker is wearing protective gloves.

From the methodological point of view, an adoption-centered design approach will be followed, involving the workers and other stakeholders, like security officers. Several design iterations will be conducted, also involving tests in simulated emergencies scenarios.

4 ARCHITECTURE AND DATA FLOW

The system comprises five main components (see Figure 1(b)):

- A network of **sensors** distributed in the industrial plant, comprising traditional ones (e.g. accelerometers, potentiometers, strain gauges) and fibre optic ones. The sensors can be wired or wireless;
- The **data acquisition board**, which is a modular and multi-channel IoT board, with wired, Bluetooth and 4G network connectivity, that acquires data from the sensors;
- The **server** stores application-specific data (*e.g.* the plant map) and runs the risk models, using data acquired from the data acquisition board, to compute the *risk-map* that associates each area in the plant to a risk value.
- The **mobile client**: the application that runs on the worker's mobile device and that provides the risk-aware navigation service;
- The **web client**: that is used by a system administration for system configuration (*e.g.*, parameters tuning, map creation). In the future, we envision this component can be used as a dashboard during emergency management, for example to report workers' positions.

During the setup phase, the system administrators configure the system, for example providing the area map and specifying the exits. They then identify the vulnerable components of the plant and tune the risk models accordingly.

When the setup phase is complete the system enters the *operational phase*, during which the data acquisition board collects data from the sensors and forwards them to the server, which runs the risk models. When the *risk-map* changes, the updated information is sent to the mobile client that can then use it to compute the routes.

The main challenge in the system is its robustness in case of *NaTech*, if any of the system components (*e.g.*, server, network, etc...) fails. In order to address this challenge, the following solutions will be adopted:

- The system supports redundant components, including sensors, data acquisition boards and servers. The servers can be installed both locally and remotely (*e.g.*, in the cloud) so that, in case the local network is unavailable, the geographic network can still be used from the mobile device;
- The client communicates with the server(s) with a communication protocol which guarantees that: (i) the server can asynchronously send data to the client, without relying on a push notification server (external Internet connection can be unavailable); (ii) the client can monitor the network status and detect when all servers are unreachable, hence assuming that there is an emergency situation. While various protocol can be adopted to provide these functions, BOSH[1] (Bidirectional-streams Over Synchronous HTTP) is a practical solution;
- The mobile client does not depend on the server(s) for route computation. Therefore, in the event of no connection to the server being available, the client can autonomously compute the route based on the available *risk-map*.

5 CONCLUSIONS

ROSSINI is an interdisciplinary project, addressing challenges in the fields of structural engineering and computer science. This paper introduces the main issues and sketches a possible solution considering the computer science aspects of the project.

The interaction of this project with the field of assistive technologies is two-fold: on one side, we expect to adapt the existing solutions and methodologies, previously proposed to support the navigation of people with visual impairments, to the problem domain of the navigation assistance in situational visual impairment use cases. On the other side, we expect the produced results to further advance the research and also benefit the field of assisted navigation for people with disabilities.

6 ACKNOWLEDGEMENT

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