

Visual Management of Shipyard Emergency

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ABSTRACT

In this paper we discuss the problems of visual interaction with emergency management systems in shipyards. After introducing the basic issues related to safety in shipyards, we present an information system and a set of visual interfaces to control the shipyard and support workers and safety responsible in case of an emergency evacuation.

Author Keywords

Yard safety, visual perception, visual communication, wireless personal device.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

The need for hosting an increasing number of people in living spaces and transports has pushed engineering and architecture towards gigantic buildings: skyscrapers and ships are becoming self-contained environments offering a set of services typical of a small town. Such a building philosophy requires a special attention to safety due to the huge number of people involved, the complex structure of spaces, the large range of activities performed inside, and the spread in people ability to react to adverse situations.

The problems and the solutions to face adverse events are different during the building of such artifacts, with respect to their normal exercise. The highly dynamic nature of a yard, the diversity of people working in it, and the nature itself of the yard as a place where heavy activities are performed, demand a different approach to safety with respect to the procedures to be adopted when the building (a skyscraper, a large factory, a cruise ship) is complete. One of the most critical problems to be faced in case of an adverse event is the evacuation of people working or living inside

the building. Any satisfactory solution to this problem is grounded on the possibility to drive the evacuation in an ordered way. Conversely, the most critical situation is to face a disordered evacuation, defined as a type of evacuation which adds damages and injuries to people beyond those due to the disaster.

Evacuation plans and associated public displays are apt in case of a stable environmental configuration. During the building of an environment plans must be changed dynamically with the evolution of the environment itself and the degree of completion. Hence, the problem doubles because not only the plan must be adapted with fast dynamics, but also it must be delivered to the workers timely.

We have developed a study with Fincantieri SpA, the largest Italian shipbuilding company, to design an information system able to assist the persons in charge of safety to elaborate dynamic evacuation plans and to control them visually. In this paper we discuss the issues related to the management of information about the ship status during the evolution of its building, the visual representation of critical situations that could lead to severe problems in case of emergency, and the delivery to workers of the details of the evacuation in case of a problem, like a large fire, possibly leading to a disaster. Information about the ship status and the communication between safety responsables and workers have been analyzed in terms of visual and acoustic interaction, taking into account the specificity of shipyards, which pose a number of constraints on the approaches and on the devices to be used.

SAFETY IN SHIPYARDS

A shipyard presents a number of issues adversely affecting safety in case of emergency, which can be grouped in three classes of constraints:

Architectural constraints. A ship is very complex and large; hosting a few thousands people during cruises, it contains a large spread of services typical of a small-to-medium town in a much smaller space. During its building its spatial configuration progresses from ample wide spaces to closed specialized rooms (Figure 1); consequently the paths for moving inside it and the visual orientation cues change frequently. Finally, the large amount of metal used limits radio communication.

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Figure 1. A view of a ship bridge before (left) and after (right) the installation of the cabins

Human constraints. Workers in a shipyard are very heterogeneous, with different base cultures and different skills. As many as 70 different languages have been counted, English being often unknown; emergency messages may be misunderstood, or not understood at all.

Organization constraints. Changes in the environment are recorded with variable delays, thus leading to inconsistency between the ship state known by the persons in charge of safety and the real state, possibly suggesting emergency actions that refer to an outdated ship configuration. The most critical concern is that workers often do not know the real danger level to which they can be exposed, possibly taking wrong decisions in case of emergency.

Actors, Perspectives and Goals

To understand the links among the activities related to safety, we briefly introduce the perspectives and the goals of the different actors: the workers, the onboard emergency workers, the rescue team, and the information system administrator.

In case of emergency, workers need to receive promptly reliable information about the direction to follow for reaching the nearest safe exit, and must be alerted if they choose the wrong way.

The goal of the onboard emergency responsible is to keep the shipyard environment safe, i.e., without obstacles along the evacuation ways, using tools to monitor overcrowding and occlusions that might diminish the ability to evacuate people.

The rescue team, that operates when the emergency is on, must be aware of the number of persons saved so far, the number of persons still in danger and their location, using the most updated information about the ship state.

The information system administrator must guarantee the continuity of operation and the continuous update of the information system.

EVACUATION MANAGEMENT

The main goals of a correct evacuation are to be fast and ordered, to give correct information to people in danger, and to keep control over the environment. They are achieved by a correct mix of prevention and intervention. Prevention mainly requires the analysis of the potential sources of emergency problems, through a network of sensors monitoring the state of the ship. Intervention requires fast delivering of correct information, as well as the limitation of damage propagation with physical or organizational means.

Therefore, an evacuation management system operates in two distinct phases: observation time and emergency time.

Observation time. During the normal work information about the ship state is collected and processed, generating knowledge about the workers flows and the rooms overcrowding. This phase prepares the system to face an evacuation in case of emergency and gives to the onboard emergency workers a way to get information on the ship environment.

Emergency time. The system delivers reliable information about how to leave the ship in safety, providing both onboard emergency workers and rescue teams with detailed information on the state of the ship, on the evacuation progress and on the number of saved people.

Both phases rely on the management and the delivery of critical information, hence depend on how the information is perceived. At last, they depend on how the information is presented, since an emergency situation benefits from pre-attentive stimuli and unbiased signals universally interpreted.

The Emergency Plan

The emergency plan is part of Fincantieri's Internal Procedure Book, and is drawn by the emergency workers supervisor at shipyard installation. The emergency plan defines

the following procedures: evaluation of the fire risk; identification of risks on board; identification of people exposed to risk; classification of the risk level; prevention measures; first assistance. The most important part of this document is the first assistance procedure, that we briefly outline.

In case of a fire start or of another risky event, everybody is compelled to report it to the firemen and to the first assistance team. Four steps follow.

1. The emergency workers visually examine the work areas looking for the fire start location. They alert the intervention teams and signal the alarm using speakers.
2. Any worker finding a fire must alert the emergency workers headquarter.
3. The emergency workers try to contain the fire, alert the emergency worker's headquarters reporting about the fire evolution, in terms of new fires and extinguished ones. At the same time the evacuation starts: the emergency workers try to control the escape routes and keep count of the number of safe people.
4. As soon as firemen and rescue teams arrive, the emergency workers transmit them all the information about the fire and the status of the evacuation.

The analysis made with Fincantieri highlighted two synthetic features able to anticipate critical situations: congestion index and flow index, respectively measuring the ratio between people and environment size and capacity, and between people flowing through passages and passage capacity. In most cases the capacity of environments and passages is fixed by safety regulations [1], but the presence of temporary occlusions due to building material and the reaction of persons to an emergency situation might reduce the capacity and cause the limits to be surpassed. We shall discuss the use of such indexes in the next section.

THE EMERGENCY MANAGEMENT SYSTEM

A ship is spatially organized in a three level hierarchy [2]: decks, which mark a vertical decomposition, main vertical

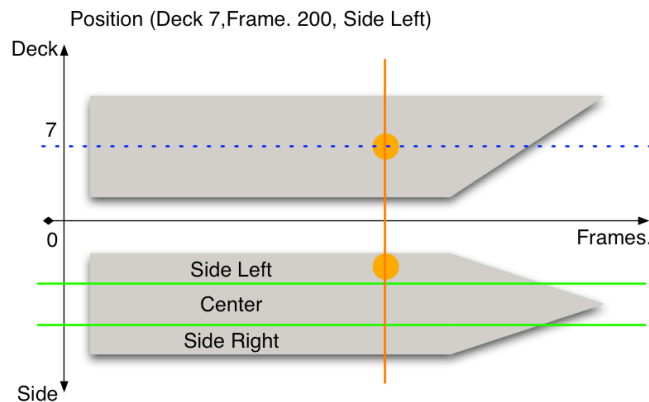


Figure 2. The ship coordinate systems

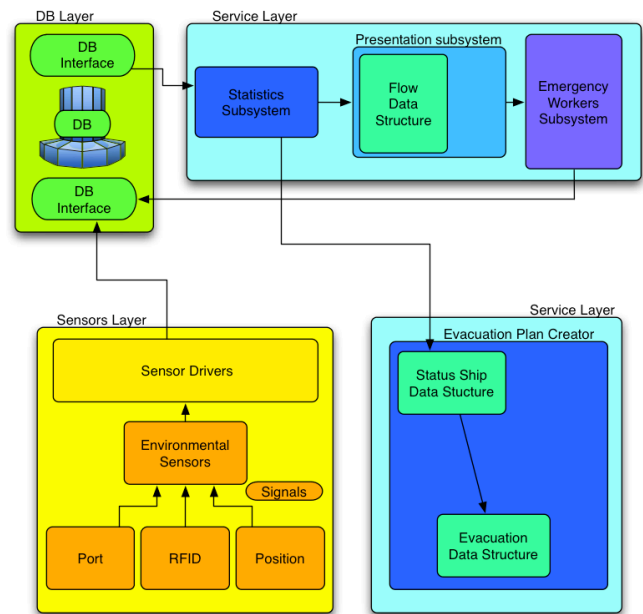


Figure 3. The emergency management system architecture

zones (MVZ) corresponding to the longitudinal watertight compartments, and rooms, like halls and cabins, which are the areas in a MVZ which can be traversed in case of an emergency, if free from temporary occlusions. At a finer detail, locations in a ship are identified by a set of coordinates related to the deck, the longitudinal frame (counted onward and backward from the rudder), and the ship side (left, center, right) as depicted in Figure 2.

A database is built around such a ship structure. It has a fixed content, describing the ship structure, and a variable content defined by data coming from sensors which monitor the ship areas during building, which change according to the actual ship state.

The emergency management system architecture is shown in Figure 3. The sensors layer manages the hardware and software (drivers) infrastructure needed to store in the database the information on the ship status.

The statistics subsystem is part of the service layer and manages a data structure containing information about overcrowding and workers flows through the different ship rooms. Raw data are read from the database and processed to initialize the statistics subsystem.

The presentation subsystem uses information from the statistics subsystem and from sensors to create visual maps about the ship and workers situation.

The evacuation plan creator, using information coming from the sensor layer, calculates the best escape ways. The evacuation plan creator stores the information in a data structure which will be used by the emergency workers subsystem.

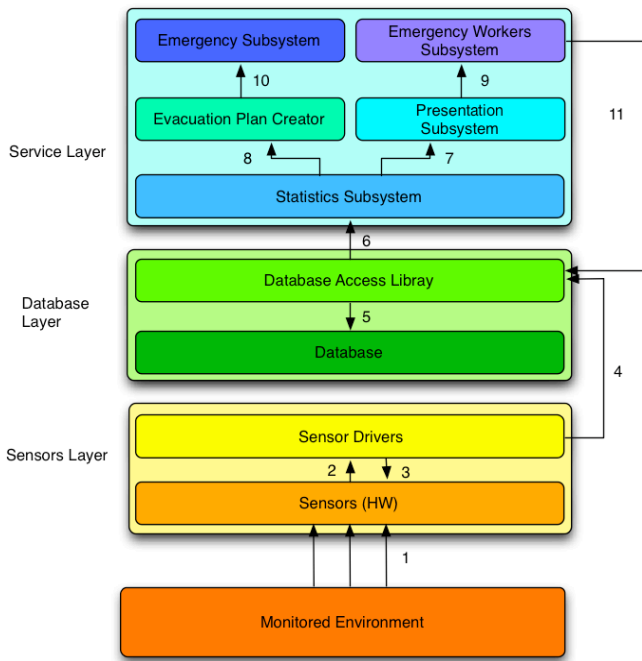


Figure 4. Information flow in the emergency management system

In case of emergency, the emergency subsystem uses the data provided by the evacuation plan creator to signal the best escape ways through the portable devices wore by the ship workers.

Figure 4 illustrates the information flow between the sensors, database and service layers.

The sensors monitor the workers' location inside the environment (1). Signals coming from the sensors are processed and converted into usable information (2); since the number of the sensors is high, sensor drivers must be able to configure the sensors' settings (3).

Sensors send updated information to the database (4). The database is constantly updated to reflect the current ship situation both in normal situation and in an emergency situation, concerning ship workers, onboard emergency workers and rescue teams involved (5).

The statistics subsystem creates and stores the data structures containing raw information related to people's flow, overcrowding and ship status (6). The raw statistic data are combined and interpreted to provide meaningful and reliable information to the onboard emergency workers (7). Collected statistic data are also used to create an evacuation plan, dynamically updated as the workers flow changes (8).

Visual information is presented on the personal devices of the onboard emergency workers (9). If the ship must be evacuated, visual information about the safe escape routes is sent to the emergency subsystem that manages the emergency panels and the workers personal displays (10).

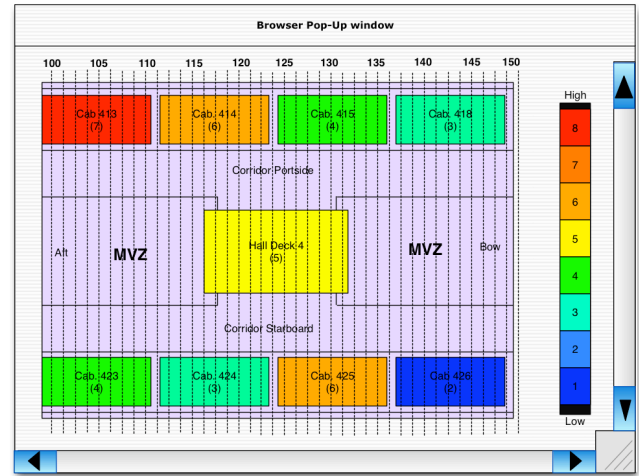


Figure 5. Visualization of room occupation

Feedback is sent to the emergency database in order to identify critical points such as persisting overcrowding, occlusions and changes in the escape routes due to the emergency evolution (11).

CHECKING OVERCROWDING AND PEOPLE FLOW

The analysis made with Fincantieri highlighted two synthetic features able to anticipate critical situations if kept under continuous control: congestion index and flow index, respectively measuring the ratio between people and environment size and capacity (hence overcrowding), and between people flowing through passages and passage capacity (hence critical situations due to people congestion). In most cases the capacity of environments and passages is fixed by safety regulations [1], but the presence of temporary occlusions due to building material and the reaction of persons to an emergency situation might reduce the capacity and cause the limits to be surpassed.

The data collected by the sensors must visually represent such information in the ship environment, i.e., corridors, rooms, open areas, etc. To display the ship environment we overlap visual information processed by the sensor level to the ship CAD project. Visualization is thus linked to the ship structure, and may concern a bridge, a MVZ across all the bridges, a MVZ of a single bridge, and the whole environment of a bridge (least level of granularity).

Information about overcrowding is represented using colors; each color represents a different level of overcrowding, as defined by a legend on the right side of the display. Warm colors represent high people concentration, cold colors represent a low people concentration. In Figure 5 the rooms of a MVZ are colored, every room has a brief description and displays the number of people inside. In such a way both qualitative and quantitative information is displayed, highlighting the real danger level.

The representation of people flow is more complex. The concept of 'passage' used in buildings, e.g., a door, is un-

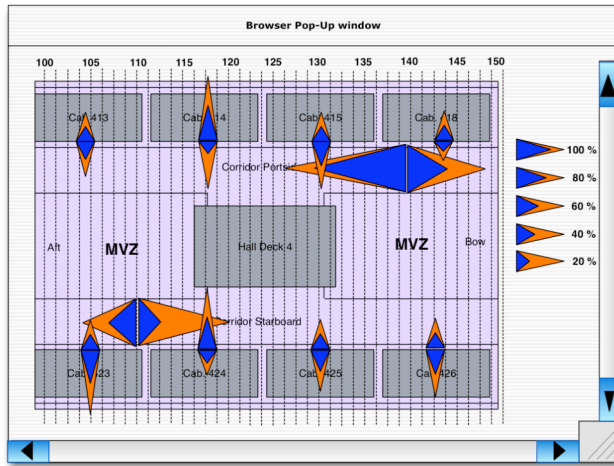


Figure 6. Visual representation of people flow across checkpoints

unsuitable in a shipyard, due to the large number of types and shapes: doors, openings, stairs, steps, etc. We use the concept of checkpoint (CKP) to define any point in the environment the number of people crossing through is limited and can be measured.

Every checkpoint has a theoretical capacity: the number of people that can cross it in a period of time without danger. Work tools and materials laying in the environment can reduce the checkpoint capacity, so we must know which is the real capacity and how much it is reduced with respect to the theoretical capacity. Both must be displayed to identify situations where the actual state of an environment or of a checkpoint could increase the risk level and lessen the evacuation speed. A similar concept is the comparison between the current people flow and the allowed flow as defined by the actual capacity, to identify situations where the dynamics of people moving could create bottlenecks and occlusions.

These two pairs of measures are represented using indicators in the shape of flames; two overlapped isosceles triangles of different color: blue for the theoretical capacity, red for the real capacity, and green/red flames for visualizing the ration between the actual flow and the capacity. Flames are drawn on the ship plan, aligned with the checkpoints. The triangle vertex represents the flow direction; the theoretical capacity, is represented in the background since it is always greater or equal to the real capacity, as depicted in Figure 6.

We used flames rather than arrows or other figures after a set of tests. An arrow would be too thin to be clearly perceived in size and color; rectangular shapes cover a larger area, hiding the information below, while a triangle is the geometric figures with the smallest area with respect to its sides. In the area of background triangle we can represent quantitative as well as qualitative information (through the

color), and the direction of the flow; overlap between the triangles immediately shows their relationship.

COMMUNICATING WITH WORKERS

Most of the information about the ship actual configuration collected during the prevention phase is used to calculate and communicate to workers the escape routes in case of emergency [2]. Such information, and the way of presenting it, depends on a number of issues:

1. Radio communication, while limited by the metal shields composing most of a ship infrastructure, is the only type of communication usable due to the dynamics of the shipyard which prevent cable deployment. Experiments have shown that frequencies above 1 GHz assure a good coverage, given that the space precision allowed (and required) is the identification of the room (in a wide sense) where the worker is.
2. Workers usually do not know the whole ship but only the part in which they work. Suggesting them a path through unknown ship areas increases the risk; longer escape paths can be safer if they cross only areas to which workers are accustomed, where they can find known visual cues.
3. Different ship areas are exposed to different risk levels. Normative institutions have issued a classification of danger in different environments [1]; a good escape route crosses areas with decreasing danger level.
4. Since people work in groups, the evacuation procedure is safer if during the escape the cohesion of the group is maintained. This principle is very important because the ability to help each other is increased by people being used to work together, by speaking the same language, by being used to understand each other, and by being able to integrate their partial knowledge of the environment into a more complete view of the situation.

To signal the escape routes three issues are important: (1) to take care of the changes in the environment due to the building progress, from a skeleton of wide spaces to a complex structure of small rooms, requiring to adapt the granularity and the range of the signals; (2) to differentiate the stimuli used to signal escape routes and wrong paths, using visual signs for positive stimuli and auditory signs for negative stimuli; (3) to avoid the use of text in favor of graphics and symbols independent from specific languages and cultures.

According to these issues, we have proposed two approaches: a weak approach and a strong approach, differentiated by the spatial granularity of signs and information delivery. In both cases we assume that workers have a personal device able to issue simple graphic signs and audio signals.

Weak approach

Workers are fed with fuzzy cues which refer to a few well known locations easy to identify according to their function. During a simulation it was evident that due to the little detail present in initial phases of ship building, environments are poorly distinguishable unless they are focal points in the ship (e.g., a hall, which can be easily recognized even if incomplete), or are connection nodes, such as stairs and elevators. Such environments are generally known by all workers, and being a few (with respect to cabins and corridors) are easily identifiable on a small personal device capable of limited detail.

Strong approach

The visual and acoustic personal device carried by each worker is used both for tracking the worker position and for driving him to a safe escape. The device is used together with environmental displays based on laser or laser-like lights with different colors marking selected crossing points such as doors and gates to be followed to reach a safe location.

Dangerous situations arise in two main cases, which define the two most frequently observed wrong behaviors: to stand still and to undertake the wrong exit or path. Visual cues are given for mistakes of small entity, while acoustic signals are used for most serious erroneous behaviors.

The personal device used for conveying to the workers the information about the escape routes must emit simple visual and acoustic signals. The device technical features are defined according to the analysis made by Fincantieri. Concerning the device positioning: (1) it must be easy to read in an emergency situation, and (2) the position sensor must not be shielded by the worker activity.

The worker might be engaged in an activity which could shield a sensor kept in a pocket or worn as a necklace. Tests have shown as a viable solution its positioning in the safety boots. However, this position prevents reading, thus the device must be split in two components: an active RFID indoor position sensor [3], and a wrist-band display, communicating via wireless connection. The two components interact with a central server, which reads the position of the worker (i.e., the room) and sends information on the escape route adapted to the worker situation.

The device works both in the weak and in the strong approach. In a strong approach, the device could be composed of a set of colored leds, making it very reliable and robust. A control and diagnostic unit must however be foreseen, to avoid the risk of delivering wrong information due to a device fault.

CHOOSING THE RIGHT APPROACH

From a general point of view, during the building of a ship the system should evolve from a weak to a strong approach.

A strong approach requires positioning a larger number of visual escape signs, and such positioning cannot be done in a highly dynamic and highly incomplete environment. A weak approach is the only viable one when the ship infrastructure is not complete.

On the other side, as the ship building proceeds, it is more equipped with stable, final safety devices, which reduce the risk of an emergency, but is less tolerant to the implant of temporary safety devices.

Moreover, while in principle a personal device is required for fast, personalized signaling of evacuation procedures, it may nevertheless be incompatible with part of the safety vest required in dedicated environments. Therefore, a strong approach, while superior, is difficult to apply on a large scale.

CONCLUSION

The evolution of an event like a fire is not impulsive or instantaneous. It starts in a localized area and may extend potentially to all the ship. But its speed allows people in charge of safety to adopt local strategies and to follow its evolution, starting with the evacuation of a limited number of people close to the fire center, and proceeding to a total evacuation only if the event cannot be controlled. A plausible strategy can be based on three elements:

1. An evacuation signal (visual and/or acoustic) must be forwarded only to people inside the area subject to an immediate risk, through the personal device and the signs in the focal locations.
2. A feedback signal must be received by the people in charge of the emergency management, by monitoring the position of people at risk, checking that they are moving in the right direction.
3. In case the feedback shows immobilized persons, the personal device can be used as a beacon to guide the rescue squad.

In this way, an up-to-date view of the event dynamics can guarantee that the emergency is under control.

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