Semantic Indoor Routes in 3D for Emergency Services applied to Buildings

Miguel-Félix Mata-Rivera[1], Alejandro Martínez-Rosales[1], Roberto Zagal-Flores[2], Joel-Omar Juárez-Gambino [2], Consuelo-Varinia García-Mendoza[2]

[1]Interdisciplinary Professional Unit on Engineering and Advanced Technologies, UPIITA-IPN,
Av. IPN 2580, Barrio La Laguna Ticomán, 07340, Mexico City, Mexico
[2] Superior School of Computer Science, ESCOM-IPN,
Lindavista, G.A. Madero, Mexico City, 07738, Mexico

mmatar@ipn.mx, mrosales81@gmail.com, rzagalf@ipn.mx,
omarjg82@gmail.com, cvgarcia@ipn.mx

Abstract. We present an approach to assist emergency services during a contingency. Particularly when they require access to the interior of buildings of more than one level, to mitigate a fire. It is important not only to find the shortest or fastest route, but also identify areas of risk and entry points as well as to identify the location of services and supplies of gas, water and electricity, among others. Knowing these data is possible to define the strategy and route of access more quickly and with greater security. This knowledge can be captured into Ontology. The system provides virtual 3D maps of buildings, displaying the location of gas pipelines, water and electrical wiring superimposed on the virtual building by layers. The routes generated on virtual scenarios unfold in the Z axis, i.e. vertically based on Dijkstra algorithm. Routes show points of access any of the floors of the building. In addition, the system offers the possibility of generating a priori route (via Web) or in situ (while accident is happening). Our case study was made within the Campus UPIITA-IPN using web browsers and Android phones.

Keywords: Semantic Indoor Routes, Emergency Services applied to Buildings

1 Introduction

Emergency services such as firefighters have the difficult task of having to face different types of emergencies, including those having to do with the attention of fires or leaks in buildings with more than one floor. This implies to generate action plans in manual way based on experience and semantic information; in order to identify possible access point and exits in one level or from one floor to other. These routes can be generated automatically using algorithms routes [12] but modifying them using mobile devices for working in vertical way and considering risks. Another common problem facing a firefighter, is that the indoor building is unknown, and in the same way to location of gas pipes, water, and electricity grid, doors, windows and stairs. In this context the approaches to interior can be adapted to be an alternative solution to this problem [13].

Without considering that in the access points, the brigade may encounter obstacles or locked doors, among other factors hindering rapid intervention in case of disasters. This other problem can be solved through the virtual models approach [12] where having a virtual 3D representation of the building, points of risk and possible access points overlap. The 3D virtual modeling and deployment, currently can already offer interaction and good performance in apps for cell phones [14], which would allow for a mobile, will be deployed on a virtual model the possible entry points and possible routes (vertical) and thereby assist in the action plan to deal with emergencies.

Moreover, having information of a building such as: number of people living and/or working in it, type of building and area (commercial, industrial, rural, hospital, etc.) would allow analyze semantically and reduce various risks, such as damages to people and surrounding infrastructure, range of fire risk at some point (e.g. a gas pipeline). Then, plan of action would be more effective. This would be possible if this information (knowledge) is captured in ontology, a similar approach is described in [15], but no ontologies were neither used nor mobile devices. Thus, in our approach a plan of action is obtained from ontology exploration and associate it with semantic rules, so that together with an algorithm of route, can offer access routes for indoor buildings to meet a contingency.

Then, considering the scenario described, an integrated approach is proposed where through the use of ontologies, virtual 3D models, and a route algorithm is generated an action plan with a set of indoor routes for buildings in an emergency event.

A prototype system with this approach was developed. In which a virtual model of a particular building is displayed, including the location of stairs, emergency stairs, elevators, gas pipes, water pipes and mains. In addition to doors and windows in order to generate routes and support the action plan in case of fire. The system has two versions: Web and mobile. The web version allowed to aided firefighters to establish routes from before the arrival of the team brigade and during the attention of the emergency. The aim is to reduce the brigade's reaction time and the risk margin.

The remainder of the paper is organized as follows. Section 2 presents the state of art while section 3 describes the modules that composes the system, design of ontology and 3D building modeling and the experimental interfaces developed so far. Section 4 shows the tests and obtained results. Finally section 5 concludes the paper and outlines further work.

2 State of Art

Nowadays, research for indoor has attained increasing attention during the last years because today a person an average spends about 90% inside a building [1]. Early research works on indoor environments appears in [2]. For example, the work in [3] uses an airport as case of study to indoor environment and presents an agent-based indoor way-finding simulation. But the Emergency Service Problems require an approach that integrate multiple technologies, in a framework for Supporting Urban Search and Rescue is used for to assist decision making during and after emergencies.

Indoor navigation is not a new concept, but in contrast to outdoor (or car) navigation, it has more and new challenges to deal with; some of them are: shape diversity, degrees of freedom in movement, granularity, and network type [5]. In the case of approaches to routes generation the history says that routing is based on graphs since road networks can easily be described as sets of nodes and edges. One popular approach to solve this problem is to focus on the topology of rooms and build a graph to represent this topology [4]. For guiding rescuers to move quickly from various entrances (within a building) to the disaster site, in[16] the authors developed a spatiotemporal optimal route algorithm for micro-scale emergency situations using real-time data for a GIS-based emergency response system. For another hand, research for routes generation combined with ontologies is focused on network analysis or in the planning process based on impedance or weight [6,7].

Ontologies have been signaled as a tool to assist in tasks of indoor environments, including the example of firefighters as possible application of the approach [9]. Moreover, navigation ontology for outdoor and indoor space is being built based on the exploration of the relationships between the two spaces [10]. In this context, SEMA4A[18] is an Ontology that includes concepts and relationships for provide emergency notifications (accessibility, emergency, communications). Now, the use of 3D models has been used to support route planning, in [8] an approach to route planning is presented according to users' widths, heights and requirements (e.g. avoid stairs). Thereby trends on indoor research suggest to explore integral approaches like is presented in this paper.

3 Framework

The architecture of the solution is composed of four modules: 1) First one is the semantic module, this contains the ontology, semantic rules, spatial and non-spatial information of the building (type, location, neighborhood, people live or work on building, among other data). This module provides the requirements to generate a route. It generates the parameters to send to the action plan module. While 2) Virtualization model handles the creation and rendering of 3D model for each building, the scenery, and displaying. In addition, it generates the queries for sending to semantic module. 3) Action plan module is the third one of the system; it manages the options of visualization, call to algorithm to generate the route (based on the requirements obtained from ontology). 4) Finally the fourth module manages the displaying option and the interaction with user. In Figure 1 is shown the general architecture with the modules described.

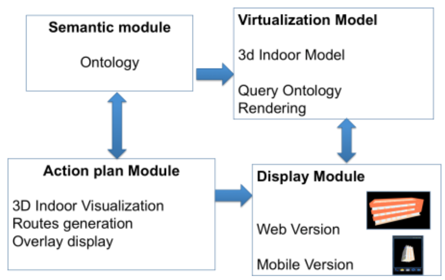

Fig. 1. Architecture of system

The general functionality of approach is based on the following scenery with a sequence of steps that show the attention process when an emergency is presented:
1) A situation emergency is presented, 2) the report of the emergency (by telephonic line) is received, 3) the report is sent to the emergency squad, who comes out to attend the emergency 4) System is accessed via web and mobile to generate an action plan (strategy) to address the incident, 5) possible plans of action are sent and displayed to the fire brigade that is in charge of the emergency.

3.1 Design of Ontology

Ontology was designed based on common procedures of fireman and brigade fire, concepts and classes are identified in order to analyze the indoor structure of building and find the access nodes and risk nodes. These data are used as an input parameters of action plan module.

The process of ontology exploration is based on the nature of B-Tree used in databases [11]. Exploration of ontology allows knowing considerations and restrictions required on a path for a particular building. The result of ontology exploration is a list of nodes. These node represent risk points and free points (trusted points), they are inserted into a vector, and these vector is send as an input parameter to the action plan module, to generate the possible indoor routes using and adaptation of Dijkstra.

Structure of ontology uses semantic relations (well-known in ontology domain) they are listed below:

- Hyponymous relationships ("is a" relation or hyponym-hyperonym), generic relation, genus-species relation: a hierarchical subordinate relation. (A is kind of B; A is subordinate to B; A is narrower than B.

- Instance-of relation. Designates the semantic relations between a general concept and individual instances of that concept.
- Locative relation: A semantic relation in whom a concept indicates a location of a thing designated by another concept.
- Meronymy, partitive relation (part-whole relation): a relationship between the whole and its parts.

Then, ontology is an upper- ontology domain, where concepts and classes capture the knowledge required to analyze a building and indicate the parameters to consider in the path generation. A snippet of Ontology is shown in Figure 2.

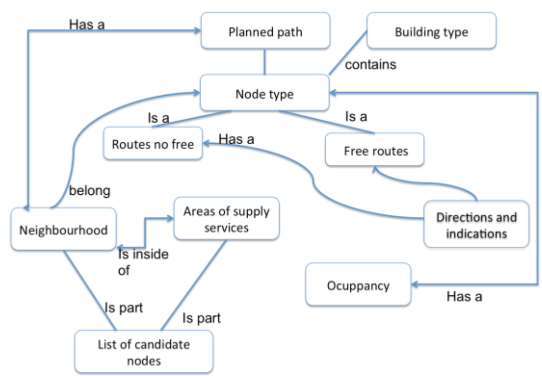

Fig. 2. Snippet of Ontology

As it can see, ontology contains concepts and classes related to analyze the possible paths the node type (hazardous, no dangerous) level of occupancy, use of building (building type) and other properties such as schedule, identification of areas where exist supply services. Semantic relations allow expressing queries in order to obtain the knowledge and help in the decision-making, this process is explained in the next section.

3.2 Semantic Query Processing

The semantic module receives the descriptive information of the building (address or location). This information is used to explore the ontology and answer semantic queries, we define some queries in order to help in case of emergency. One of the first aspects to know in the case of emergency is to know the location of hazard materials o dangerous areas. It is expressed in the query 1.

Q_1= {Find places contains hazardous materials inside the building}

Ontology is explored with an adaptation of the algorithm to explore B-Tree. When the class and concepts are found, the neighborhood nodes of them are extracted and stored into a vector. This vector is send to the virtualization model in order to display and generate the model of building with risk point and secure points. As a result the areas or spaces containing hazardous materials in the building are shown with a dot red line in its contour. It is shown in Figure 3.

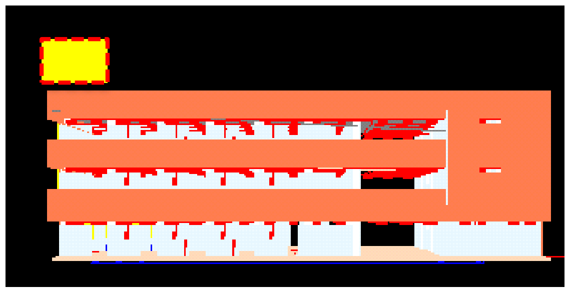

Fig. 3. Hazardous places (dot red line) identified in building

Here, it is possible retrieving semantic information such as: It is located in level 3 , in the surrounding areas is found a laboratory with 18 person working throughout academic hours, the hazard material type is gas. Other required data is identify all risk points and exit points, this is made using the query 2, and the result is shown in Figure 4 where exit points are displayed using green squares.

Q_2= {Retrieve all risk points and exit doors}

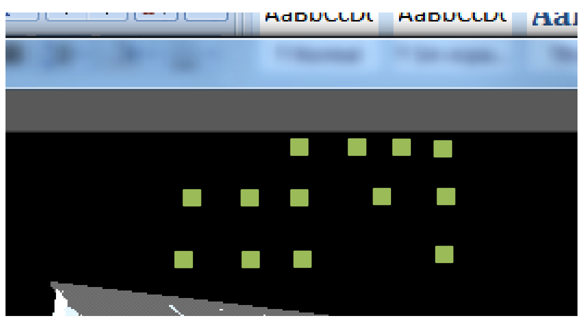

Fig. 4. Hazardous places (dot red line) identified in building

While, in query 3 is possible to know an estimated number of people in the building. In addition, use of the space and people involve in it. This information is useful to know all possible entry point and planning for evacuation.

Q_3= {Retrieving occupancy information}

In that way, is semantically processed the information, and displayed on a virtual model in 3D. In the next section is explained how is build the 3D model.

3.3 Buildings Modeling

The construction of 3D model is based on two steps: the first one is to take architectonic drawing of building as a basis of model 3D construction. In Figure 3, side view of a building (semi-automatically generated from building drawings) indicating vertical routes to access the different levels of the building is shown. Secondly, all vertices that make up the building are loaded: external walls, internal walls, columns, stairs, etc. which will become property of a scenario in which the model (building) will be displayed and additionally will allow the capture of events, so that the user can interact with the model. Figure 5 shows the result of this step.

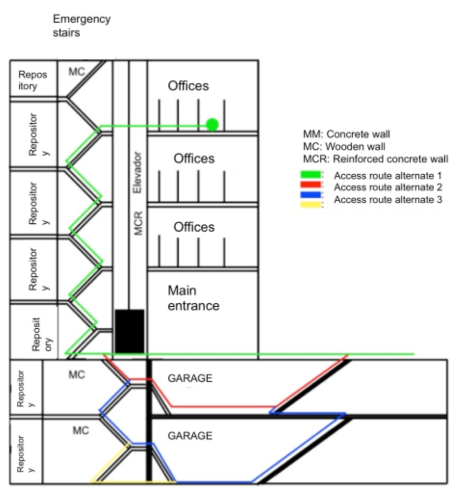

Fig. 5. Lateral View Building and possible routes (in red, green and yellow)

Each view model requires three classes that are deploying the model, the first one allow interaction with elements of itself, the second is the one who draws and rendering the model; the third is one that detects the angle from which displays the model. The resulting model is shown in Figure 6 where elements are seen in yellow (gas pipelines and gas stationary) elements in blue represent water pipelines and the water tank). Moreover, elements in red, representing electrical wiring and power stations.

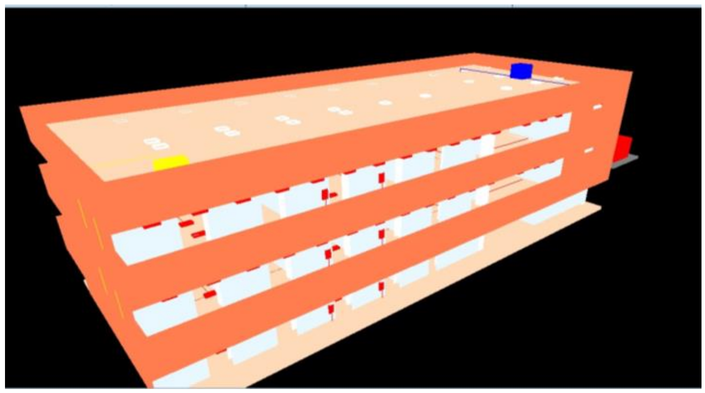

Fig. 6. Model of Building in 3D obtained from drawings

As explained overall functionality of the modules is now proceeds to show the tests and results in the next section.

4 Results

In this section, is shown the interfaces developed, for a simulated case of fire event, and evacuation plan as an emergency. Testing was made using a cellular phone with android 2.3 for mobile version. While, the web version was tested using Google Chrome version 42.0.2311.152 (64-bit). Firstly, the model of building is displayed with all layers (a layer contains a service supply) with a checkbox is possible to overlay each layer in the model. This is shown in Figure 7

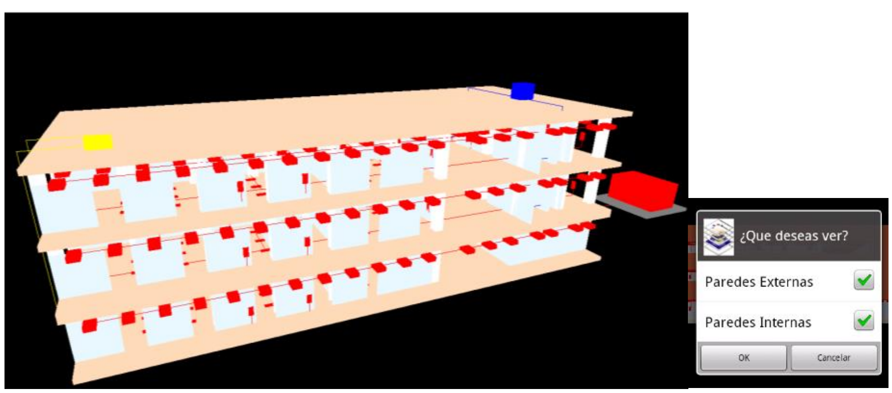

Fig. 7. Views supplies (electric mains, water and gas pipelines) in the building

Figure 7 display all the supplies services found in a building, in this case, in red appears electric mains, in blue color the water pipelines and finally in yellow the gas pipelines as displayed. The system allows selection through the layers, filtering the elements or services that are displayed. In addition, system shows the action plan or the routes as an instructions in text mode. It is shown in Figure 8a, while in Figure 8b, a possible evacuation route when an emergency has occurred is shown with a green line (in this case the danger is present in the rooftop, while people is located in first level, at west side, then the evacuation route is shown from west to east, and from first level to ground floor. These results are shown using mobile devices.

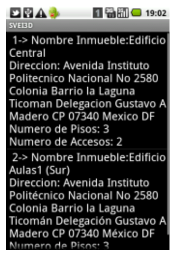

Fig. 8a routes instruction in mobile version

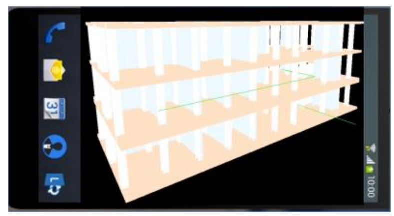

Fig. 8b routes in mobile version

Routes generation is shown when a fire is not present, it is shown in Figure 9a, while when danger is present the Figure 9b shows the trusted routes.

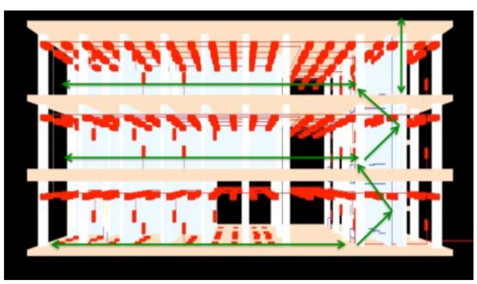

Fig. 9a trusted routes (in green color)

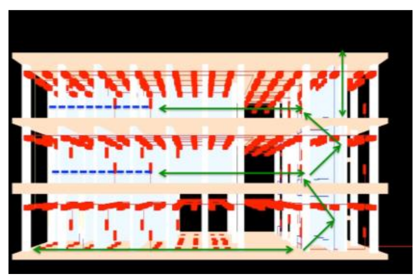

Fig. 9b risk routes (in blue color)

5 Conclusions and Future work

Currently, fire brigades and have minimal knowledge of the interior of a building, even though there are tools and maps to assess around before reaching the site of the disaster. This means, much time will be lost in the generation and evaluation of the plan of action. In fact, having this information a priori or to generate automatically. It will increase the chances of rescuing civilians, while rescuers are less exposed to serious situations inside. The 3D models are a good choice to make a visual analysis, while ontologies can generate the action plan based on recommendations and procedures. The integration of ontologies, 3D model, route algorithm, indoor approach and mobile technology, allow offering a new possibility based on mobile devices making tasks to assist in real time in cases of fire o evacuation plan. In these cases, precise information is vital to avoid injury in people and damage in infrastructure and surrounding areas when an emergency occurs. The tests show that the approach is promising and useful. The future work is to integrate command voice, and interactions using augmented reality, in particular it could be useful when the brigade is in situ and helping in real time.

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