Increasing Situational Awareness of Indoor Emergency Simulation Using Multilayered Ontology-Based Floor Plan Representation

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Abstract. Indoor emergency is a challenging research domain. It has to deal with dynamic situations, unexpected consequence of incidents, many entities involved such as human and building elements. Emergency simulation cannot avoid these various and dynamic information. This research proposes a multilayer of ontology-based floor plan representation in order to describe how the simulation goes with these complexities. Our approach uses ontology to model a floor plan into various perspectives e.g., *AccessibilityPerspective*, *ControllingPerspective*. Each perspective is used to support different purposes. For example, *AccessibilityPerspective* is used for way finding and navigation. These perspectives are represented by multilayer of graphs, one perspective per one graph. The research objective is to increase users' situational awareness in the indoor emergency simulation. The are two main advantages in this model. First is a capability to handle dynamic situations and consequences of emergency using ontology and inference rules. Second is the use of multilayered graph-based representation in describing the floor plan's situation in various perspectives and overcoming information overload. With these advantages, users can notice how the simulation goes, what and where have been changed in a glance.

Keywords: Multilayered floor plan representation, ontology based modeling, emergency situation.

1 Introduction

Indoor emergency is a complicated research domain. There are many changes and unexpected consequences caused by emergency incidents. This research domain also has to consider about relationship between components in various perspectives. For example, *AccessibilityPerspective*: elevator L can let ones from the first floor to access the second floor, *PowerControllingPerspective*: room R provides the electricity to the west area of the building. When an emergency happened, let follow the previous examples, room R may get some damage and

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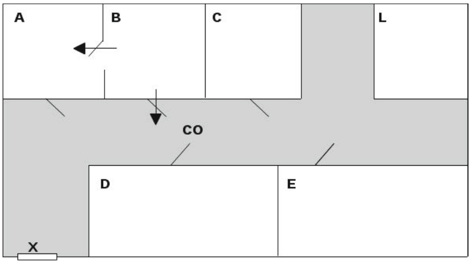


Fig. 1. An example of floor plan that consists of rooms (A, B, C, D, and E), an elevator (L), an exit (X) and a corridor (CO). Room B is a power control room that supplies electricity to the whole floor. This room is locked. It requires a key to access.

cannot provide electricity to the building anymore. Consequently, elevator L which located at the west area of the building cannot work properly. Finally, elevator L cannot be used to access to other floors. For such scenario, indoor emergency is quite complex and some relationship may be not very obvious to notice. Consequences of the incident are dynamically changes and not easy to handle. This paper propose a floor plan representation that can handle these dynamic challenges in various perspectives. We design our approach from the simulation monitoring point of view. Its objective is to increase the situational awareness [5] of indoor emergency simulation. However, since the representation have to handle information from multiple perspectives. There are many researches tried to represent a floor plan from the same purpose. Nevertheless, they seem to face problem of information overload when they had to deal with many perspectives. This paper proposes an approach to represent a floor plan in multilayer of graph, one perspective per one graph.

2 Related Works

There are series of studies indicate that the average person spends around 90% of their time indoor [1], [4]. Therefore, it is important to investigate the indoor space for our better daily life. From the navigation perspective, indoor space and outdoor space have similarities and differences [8]. For example, they share common concepts of *Passage*, *Portal* and *Barrier*. On the other hand, distances and angles play the key role for outdoor space but not much for indoor space. In indoor space, the topology plays a more prominent role. For example, connectivity becomes more important than direction. Moreover, indoor space is a kind of isolated space. We can neglect some uncontrollable factors, such as weather, in this space. However, it is still complex enough to be an interesting research domain. For example, the indoor landmarks are generally local ones because corners or wall can block our vision. Furthermore, some of them can be moved easily.

Many floor plan representation approaches have been proposed. A floor plan can be modeled in various approaches — graph-based, grid-based, 2D or 3D spatial space, ontology — to serve with different purposes e.g., navigation, tracking, simulation, visualization [3]. To represent an indoor space in multi perspectives, Bigraph is proposed by [7]. Bigraph is a visualization that combine two semantic graphs named *Place graph* and *Link graph* together. Place graph is a graph representing floor plan structure. Link graph is a special graph representing other relationship concepts between nodes in the graph. For example, representing the Internet connection between rooms in the building, representing an agent A_1 is using a computer C_1. For another example, Becker T. also proposed a multilayered space model for indoor navigation purpose [2]. The model mainly illustrated the combination of topological layer and sensor layer for navigation and positioning purposes, respectively. It required special edges, *joint-state edges*, to describe relationship of nodes between layers e.g., room A is under the range of sensor S. However, similar to Bigraph's issue, even those models can represent multiple perspectives of indoor floor plan, all perspectives are depeiceted in a single visualization planar. To handle multiple perspectives, those models are easily to reach information overload problem. For example, to represent the network connection between rooms in a building and topological accessibility between those rooms at once. In such case, instead of the representation enhances the floor plan visualization, it may become too hard to understand. Moreover, those approaches were not designed to handle consequences of dynamic situation.

3 Methodology

Our research wants to make the floor plan visualization simpler regarding to handle a floor plan representation in multiple perspectives. We propose an approach that using ontology to capture a floor plan concepts in various perspectives and represent them with multilayer of graph. The ontology is not used only to capture the floor plan's concepts, but also be used to handle dynamic situation due to the changes or consequences in indoor emergency domain.

For understanding more clearly, we describe our model with a sample scenario of indoor emergency. We use this scenario and others to evaluate our proposed model.

3.1 Scenario

Fig. 1 represents a floor plan structure. A, B, C, D and E are rooms in the building. B is assigned as a power control room which provide electricity to the whole building. Moreover, this room is locked from outside, to enter the room requires a key. L is an elevator which requires electricity to be in operation. X is an exit door and CO is a corridor. The emergency scenario is described as followed: "When an unexpected situation happens, a power control B cannot provide the electricity to appliances nor places." Based on this incidents information, what we should get from our model? Since the power is failure, the elevator L cannot operate to any purpose. Consequently, It should be classified as an obstacle element for escape purpose. The room B could be labeled as a *DangerousPlace* because it got damaged till out of function. Its neighboring rooms, A and C, are also defined as *WatchOutPlace* since they have some risk by being the rooms next door to room B.

3.2 Ontology

The core part of our ontology is depicted in Fig.2. Some part of them share the common components with OntoNav [6], however, our approach do not cosider only "Navigation" purpose. We consider on virious perspectives such as *AccessibilityPerspective*, *NeighborPerspective* and *ControllingPerspective.* Their descriptions are shown as followed:

- **AccessibilityPerspective** considers about how the *StructureComponents* e.g., Room, Corridor possibly connect. The distance between components does not matter. For example, in Fig.1, room B and C are next to each other. However, they cannot access to each other because there is no door linking between them.
- **NeighborhoodPerspective** considers in the component's location, not for the connectivity. For example, In Fig.1, There is only one direct connection between room A and room B. However, all rooms, A, B and C, are considered as neighborhood because they are close to each other in structure. In this perspective, it is possible to have neighboring link even there is no accessibility relationship.
- **ControllingPerspective** mainly considers in the element controlling e.g., electricity, water. This is an important information. Many consequences will be happened up to this perspective.

3.3 Reasoning and Inference Rules

To handle consequences of incident, we use inference rules to deal with dynamic information. For example, an Incident I is happened. It causes a consequence C_1. Then this C_1 also triggers a new rule and causes another new consequence C_2 happends. As mentioned scenario in Section 3.1, a power control room B has an incident e.g., fire. This incident causes room B as a dangerous place. Since room B is a power control room that supplies electricity to other places and alliances in the floor, including the elevator L. This matter causes the elevator L becomes an inoperating place. Finally, the elevator L is classified as *InaccessiblePlace.* In other words, our model can show how *PowerControllingPerspective* causes consequences on *AccessibilityPerspective.* Some sample rules are showed in the following equations.

$$Place(?X) \cap hasProperty(?X, DANGEROUS) \rightarrow DangerousPlace(?X) \quad (1)$$

$$DangerousPlace(?X) \cap hasPowerSupply(?X, ?Y) \cap RequireElectricity(?Y) \rightarrow Inoperating(?Y) \quad (2)$$

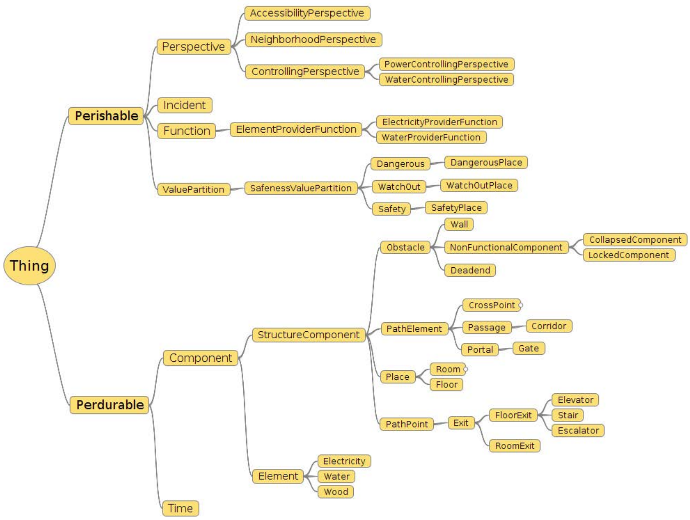


Fig. 2. Example of ontology design describing a floor plan

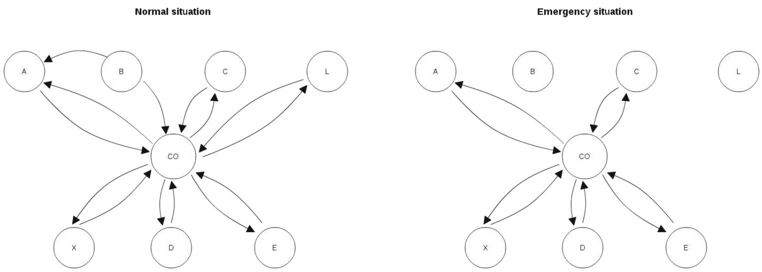
$$Inoperating(?X) \cap Place(?X) \rightarrow Inaccessible(?X) \tag{3}$$

3.4 Graph-Based Representation

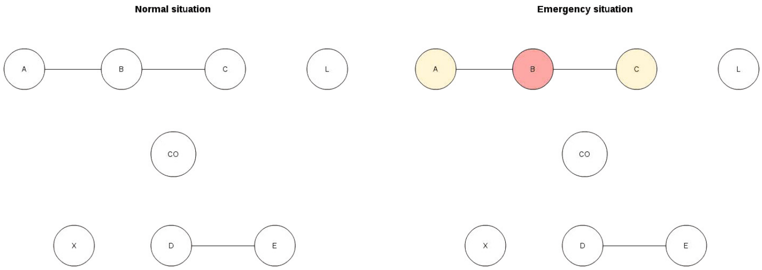
To represent each perspective with a graph, we query classes having association with properties that related to the interested perspective. For example, to represent a graph of *NeighboringPerspective*, the system queries *hasNeighobr(?X, ?Y)* to ontology. This querying retrieves a list of node X and Y that have property *hasNeighbor*. Then the system draw a graph of *NeighboringPerspective* based on the result list as showed in Fig.3b. In order to handle dynamic in emergency situation, once the inference rules produce some changes, the drawing graph module is activated.

4 Discussion and Future Work

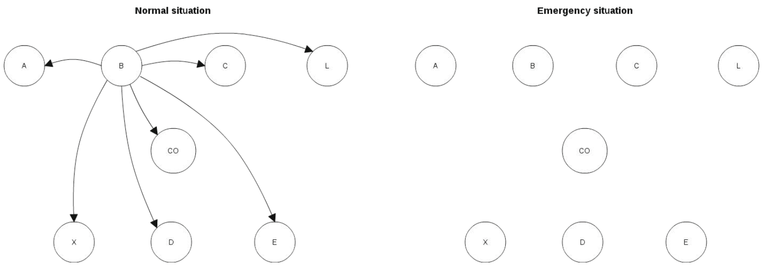
This work proposes a multilayer of ontology-based floor plan representation for supporting ontology-based indoor emergency simulation. Ontology is used to capture concepts of a floor plan in various perspectives and to link relationship among them. Perspectives are represented by multilayer of graphs. Its objectives are to increase users' situational awareness and to describe how the simualtion goes with the incident scenarios. From the scenario given in the previous section, our research shows two advantages — capability of handling dynamic-situation using ontology and inference rules, and the use of multilayered graph-based representation to lessen the information overload issue. For the future work, we



(a) Accessibility layer in normal and emergency situation.



(b) Neighboring layer in normal and emergency situation.



(c) Power control layer in normal and emergency situation.

Fig. 3. Representation graphs of various perspectives based on the given scenario and the floor plan in Fig.1. The left column images represent a normal situation. The right column images represent an emergency situation that an incident happened in the room *B*. The red and orange nodes in (b) represent *DangerousPlace* and *WatchOutPlace*, respectively.

plan to adopt this research idea with a more complicated scenario simulation. For example, to add human ontology to the scenario and explore how the dynamic environment affect the human behavior. However, this research still has some limitation. Since this representation focus on topological perspective e.g., accessibility, connectivity than geometrical perspective e.g., distance, direction. It might not be so convenient to the very-end-users.

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