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Multi-Agent Simulation of Wayfinding for Rescue Operation during Building Fire

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Abstract**—**Recently research on human wayfinding has focused mainly on mental representations rather than processes of wayfinding. The objective of this paper is to demonstrate the rationality behind applying multi-agent simulation paradigm to the modeling of rescuer team wayfinding in order to develop computational theory of perceptual wayfinding in crisis situations using image schemata and affordances, which explains how people find a specific destination in an unfamiliar building such as a hospital. The hypothesis of this paper is that successful navigation is possible if the agents are able to make the correct decision through well-defined cues in critical cases, so the design of the building signage is evaluated through the multi-agent-based simulation. In addition, a special case of wayfinding in a building, finding one's way through three hospitals, is used to demonstrate the model. Thereby, total rescue time for rescue operation during building fire is computed. This paper discuses the computed rescue time for various signage localization and provides experimental result for optimization of building signage design. Therefore the most appropriate signage design resulted in the shortest total rescue time in various situations.

Keywords**—**Multi-Agent system (MAS), Spatial Cognition, Wayfinding, Indoor Environment, Geospatial Information System (GIS).

I. Introduction

WITHIN unfamiliar and particularly unbuilt environments, fewer predictions can be made about environmental structure and navigation of people depend on external information or what Norman calls "knowledge in the world" [1]. Such knowledge resides in the environment and is communicated through signs, guidance systems, and architectural clues. The goal of this research is to reach rescue team's wayfinding and rescue process using optimum placement of building signage which helps them finding the fire location in a safer way.

Since the costs of practical simulations cannot be easily supported, rescue simulations with computers became rampant within the last years [2]. Geospatial information systems (GIS) can be widely used to predict horrible events. However, in using only GIS could not be suitable solution for solving serious problems in complex building caused by building fire. Therefore, it is recommended to consider intelligent approaches such as multi-agent-based wayfinding simulation in the stressful situations [3].

The previous research focused on the agent-based simulation of human behavior and was developed a computational theory of perceptual wayfinding [4]. In addition, there are a number of investigations were depicted people's wayfinding behavior in unfamiliar buildings by acquiring cognitive maps [5], [6]. There is considerable research in emergency simulation by using GIS multi-agent-based models. Arai et al. (2012) and Goetz et al.(2012) present an allocation model for rescue disabled persons in disaster area with help of volunteers using integration of GIS and multi-agent-based model. In this research, GIS is used to present road network with attributes to indicate the road conditions and Volunteers and disabled persons are modeled as agents [7], [8]. Zaharia et al. (2011) proposes agent-based model for the emergency route simulation by taking into account the problem of uncharacteristic action of people under distress condition caused by disaster [9]. Cole (2005) studied on GIS agent-based technology for emergency simulation [10]. This research discusses about the simulation of crowding, panic and disaster management and there is further research works are accomplished based on Agent-Based Indoor Evacuation Simulation of wayfinding [11], [8], [12]. Drogoul and Quang (2008) discuss the intersection between two research fields: multi-agent system and computer simulation [13]. This paper also presents some of the current agent-based platforms such as NetLogo, Mason, Repast. In addition, some researchers have introduced several multi-agent strategies for pedestrian optimal wayfinding through interior complex building [14]-[16].

Through the view of these researches, this study focus mainly on multi-agent simulation (MAS) of some aspects of the process of wayfinding on rescue operation which is computed the total rescue time reaching the fire location for various building signage design. MAS have to give actors different abilities and goals, to communicate in the common environment through the Interaction between the environmental messages delivery systems. In this paper, second floor of three hospitals are supposed to be in fire, in rescue operations there is rescue teams who are assumed as agents and can act autonomously based on their own rules and would use the signs and topological specifications for reaching to their goals.

The rest of this paper is organized as follows: Section II presents more important concept in the area of agent

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containing affordance, multi-agent-system, peer-to-pear communication and NetLogo environment. Section III introduces methodology and conceptual model of rescue operation, on which the model is founded. Section IV applies this process model to a hypothetical emergency scenario. Section V discusses the application. Section VI presents conclusions and directions for future research.

II. Background

A. Definition of a Multi-agent Systems

According to the heterogeneity of the involved fields there is no common agreement about a definition of the term agent [17]. An agent can be anything, such as a robot that perceives its environment through sensors and acts upon it through effectors [18]. This definition is shown in Fig. 1. More specifically, agents are considered computer systems that are situated in some environment and can act autonomously [19].

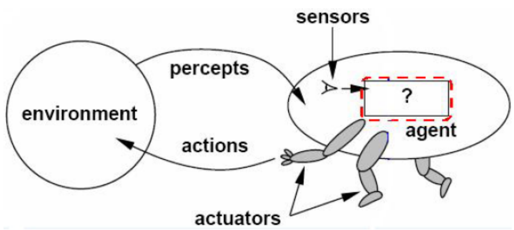

Fig. 1 An agent in its environment [19]

Agents can be represented as functions that map percepts to actions. Abstract models of agents distinguish between purely reactive agents, agents with subsystems for perception and action, and agents with state. These abstract models can be implemented in different ways, depending on how the decision-making of the agent is realized [15].

Multi-agent systems (MAS) depict systems as a combination of multiple autonomous and independent agents and are therefore well suited to simulate collaboration of different actors.

Adapting the definition of Ferber (1999) the term multi-agent system refers to a system consisting of the following parts [20]:

- The environment E consisting of the following elements:
  - A set of objects *O*: Objects can be perceived, created, destroyed and modified by agents.
  - A set of agents A: Agents are a subset of objects ($A \subseteq O$) capable of performing actions (the active entities of the system).
  - A set of locations L determining the possible position of the objects (from the set *O*) in space.
- An assembly of relations R which link objects and also agents to each other.
- A set of operations *Op* enabling the possibility for agents to perceive, manipulate, create, destroy objects of *O*, in particular representing the agents' actions.
- A set of operators *U* with the task of representing the application of the operations from *Op* and the reactions of the world to this attempt of modification. The operators from *U* are called the laws of the universe.

B. Agent Architectures

The main criteria distinguishing architectures is the question of how much internal representation of the world the agents should have. Reactive systems have less or no internal representations, whereas systems constructed according to the deliberative approach have only symbolic representations. An agent constructed after the reactive approach purely reacts to its current percepts following condition-action rules. Deliberative architectures follow the classical AI approach (the Sense-Plan-Act paradigm [21]) that decomposes the control system of an agent into three elements: the sensing system, the planning system, and the execution system. The agent plans its actions based on its percepts and knowledge. The control flow between the three components is unidirectional from the sensor to the effector. The agent architecture presented in this subsection follows the Sense-Plan-Act paradigm.

The interaction between the agents and the environment defines the dynamics of the multi-agent system [22]. This interaction is determined by the decision making process of the agent about the actions to perform (operations from the set Op) and the reaction of the environment to these actions (operations from the set U). The structure of the decision making process provides the foundation of the agent architecture. It can be divided into two components: the perception subprocess and the decision subprocess. An agent can be described by a function perceive and a function decision [21]:

$$\text{perceive} \ : E \rightarrow P^* \qquad (1)$$

The function perceives represents the perception process of the agent. It maps the environment to a set of percepts. The realization of the function decision representing the decision making process of the agent depends on the selected architecture. Agent architectures can be distinguished according to the implementation of the decision function. Here we distinguish two classes of agent architectures:

- reactive agents
- agents with internal state

To allow higher-level internal capabilities of the agents, such as planning, goal directed behavior and collection of experiences, an internal representation of the world is necessary and not possible without internal state.

A purely reactive agent is characterized by the fact that it directly maps input to output, i.e., percepts to actions. The function decision of the reactive agent is a function of the following type [21]:

$$\text{decision} \ : P^* \rightarrow A \qquad (2)$$

It transforms a set of percepts P into an action A.

For agents with internal state the decision function has a more complex form. It includes the built-in knowledge, i.e., the former experiences of the agent, into the decision making process[21].

$$\text{decision} : P^* \times I \rightarrow A \quad (3)$$

The decision function maps a set of percepts and the current internal state I of the agent into an action A.

The decision function consists of two steps. The first step (the function updStateP) updates the internal state of the agent based on its percepts; the second step (function act) selects an action based on the updated internal state [21].

$$\text{updStateP} : P^* \times I \rightarrow I \quad (4)$$

$$\text{act} : I \rightarrow A \quad (5)$$

The function runEnv represents the reaction of the environment to the agents' actions.

$$\text{runEnv} : E \times A^* \rightarrow E \quad (6)$$

It maps the environment E and a set of actions performed by the agents to a new state of the environment. This mapping function realizes the changes on objects (including agents) caused by the agents' actions; other changes in dynamic environments are also possible.

C. Cognitive, Spatial Multi-agent Systems

With proposed approach, software agents are constructed that act in artificial environments. These environments are intended to represent parts of the real world which are interested in, i.e., for the simulation of cognitive, spatial processes.

Mark et al. in 1999s present a hypothetical information flow model for spatial and geographical cognition, which consists of four stages: acquisition of geographical knowledge, mental representation of geographical knowledge, knowledge use, and communication of geographical information [23]. Within this paper, used approach is focused on all four of them: the agents perceive their environments, form beliefs about the environment, use these beliefs to decide upon actions, and communicate with other agents. Agents with internal state are necessary to provide sufficient capabilities for the representation of cognitive processes. The function *decision* provides a general definition of cognitive processes describing these processes as a mapping from percepts and internal world representations of the agent (the internal state) to activities the agent performs in its environment.

An explicit representation of space is provided by the set of locations *L*. Agents can change the location of objects in space by their actions. The function *runEnv* represents reactions of the environment to the agents' modifications. It defines the general rules for change in the environment (the laws of the universe *U*). A cognitive spatial multi-agent system defines a qualitative notion of time represented by the change of the system from one world state to the next (i.e., a time discrete simulation). The transition is realized by the operation *runEnv*.

D. Affordance Representation

The term affordance was introduced by Gibson in 1978s who investigated how people perceive their environment [24]. Gibson described the process of perception as the extraction of invariants from the stimulus flux and called these invariants affordances [25]. Affordances are what objects or things offer people to do with them. Therefore, they create potential activities for users. Norman in1988s investigated affordances of everyday things, such as doors, telephones, and radios, and argued that they provide strong clues to the operation of such things [26]. He characterized affordances as results from the mental interpretation of things, based on people's past knowledge and experiences which are applied to the perception of these things. Affordances, therefore, play a key role in an experiential view of space [27], because they offer a user-centered perspective.

Kuhn in 2000s applied the theory of affordances to spatialized user interfaces. Affordances of physical space are mapped to abstract computational domains through spatial metaphors in order to bring human-computer interaction closer to people's experiences with real-world objects [28]. Kuhn groups spatial affordances into four categories including: affordances for (1) an individual user (e.g., move), (2) a user and an individual entity (e.g., objectify), (3) a user and multiple entities (e.g., differentiate), and (4) groups of users (e.g., communicate), reflecting different task situations. In order to know what passengers can do at an airport one has to find out what spatial affordances the architecture and objects of an airport can offer for people's wayfinding [28]. Examples for each of Kuhn's categories in relation to a fired hospital space are "moving from passage to the fire location", "perceiving and interpreting a sign", "differentiating fire locations", and "communicating with other rescuer at the hospital" [29].

E. Common Platforms of Multi-agent Systems

Developing tools for multi-agent simulations has always been an active area of research, with emphasis being laid on different aspects architecture, scalability, efficiency, fault-tolerance and effectiveness of the system.

Several Agent Based Model (ABM) tools are currently available on the market presenting different functionalities, graphical interfaces and also programming languages. As examples, it is possible to refer Repast [30], Swarm [31] NetLogo [32]) and Mason [33].The scope of this research is not to survey in detail the available ABMs but instead to briefly analyses and compare the tools based on previous surveys that already provide detailed analysis of the most important available ABM tools. A summary of some of the most important key points regarding the evaluation of the MASON, NetLogo, Swarm and Repast can be found at Table I.

TABLE I
CHARACTERISTICS OF SOME ABM PLATFORMS [34]

Characteristics	MASON	NetLogo	Swarm	Repast
Availability (free)	Good	Good	Good	Good
Maturity	Poor	Fair	Good	Fair
Programming effort	Poor	Good	Fair	Poor
Change of properties	Poor	Fair	Poor	Good
User interface	Poor	Good	Poor	Good
Simulation speed	Good	Fair	Fair	Good
Documentation	Good	Good	Fair	Fair

According Table I, there is no perfect platform to be used, being the choice of the correct ABM dependent of the task to be performed and the skills of the person who will make that task. In short, to starters and to a certain degree of complexity, the NetLogo platform is the right choice, due to the conjunction of ease of learning and power capabilities, combined with the good available documentation. When the complexity of the system grows up, requiring simulation speed, Repast is a good choice instead of NetLogo, losing however the user friendly aspect. Another conclusion from these surveys is that the users must also be aware of the constant change and evolution of these tools and that their exploration and comparison is a hard task.

III. METHODOLOGY

The navigating human is viewed as an agent with state and performs actions such as perceiving information from the real world and moving through the environment. According to Fig. 2, in the first tier, is considered states of the real-world environment, which are mapped to simulated environment states. In the second tier, is assumed beliefs of a person about the environment. These beliefs are the result of perception which are mapped to simulated beliefs of the agent. Accordingly, percepts and actions in the real world are mapped to simulated percepts^{sim} and simulated actions^{sim}. The two-tiered approach allows for the integration of people's incomplete and imprecise knowledge derived from imperfect observations of space [35]. Furthermore, it is possible to model the perception and representation of parts, i.e., subsets, of the environment. This is important because people's knowledge of the empirical world is gained by making observations of parts of the world-resulting in subsets of affordances. A geospatial space is too large and complex to allow for the observation of everything at once.

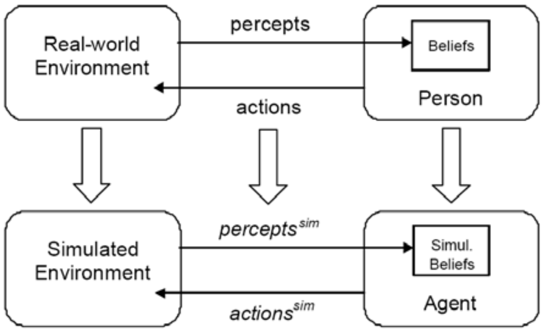

Fig. 2 Mapping from real world to simulation within a two-tiered model [4]

Given a sequence of landmarks between the current position and a desired destination, the agent executes the appropriate steps necessary to reach the destination point. Most of the wayfinding problems are due to the poor quality of the building signage or lack of them in some critical decision points [8]. Therefore, designing signage is an important task which is done and analyzed successfully in order to gain the most optimum design and placement of the building cues. Fig. 3 shows the agent's state at a decision point.

Fig. 3 Decision taken at every decision-point [36]

The centralized rescue model is presented which has two types of agent: cognizing agent containing rescue team (wayfinders and firemen) and non-cognizing agent including fire, sign and route network. The route network is also considered as an agent because the condition of fire in certain route can be changed when disaster occurs. The general rescue model is shown in Fig. 4.

The perceptual wayfinding model integrates the agent's cognitive schema and perceptual structures within the Sense-Plan-Act framework. It focuses on knowledge in the world to explain the actions of the agent during its performance of a wayfinding task.

The environment provides percepts-affordances and information from cognizing agents and non-cognizing agents to the agent; the agent decides upon and performs actions in the environment, which in turn provides new percepts; and so on. Information such as from signs is necessary for the agent

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to decide upon which affordances to utilize. The internal cognitive schema guides the agent's processes of perception, decision, and action during the wayfinding task. Information about the task and goal, wayfinding strategies, and commonsense knowledge, are necessary for the agent to perform the task. The task description directs the visual perception in such a way that the agent samples only task-relevant affordances and information, therefore, only a subset of all affordances and information present in the environment. The perceptual wayfinding model concentrates on the actual information needs during wayfinding and does not focus on learning the spatial environment because the main scope of this research is cognitive and multi-agent wayfinding using image schemata. The perceptual wayfinding model concentrates on the actual information needs during wayfinding and does not focus on learning the spatial environment.

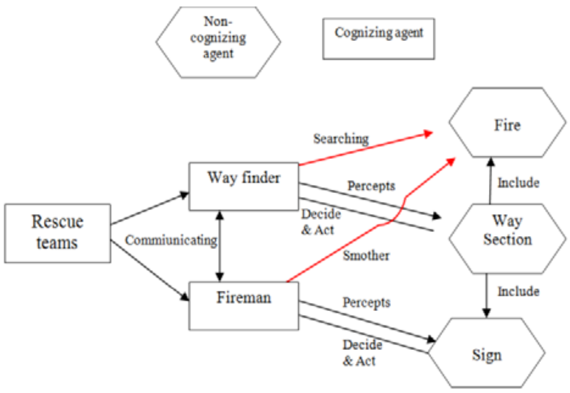

Fig. 4 Conceptual model of multi-agent rescue operation

Formalizing the conceptual model for the cognizing agent allows describing it more precisely than by using a verbal description and to create a practical tool for simulating the test case (Fig. 5).

In this paper, three kinds of agents are assumed such as environment including Signs, Fire and rescue team including fireman and wayfinder.

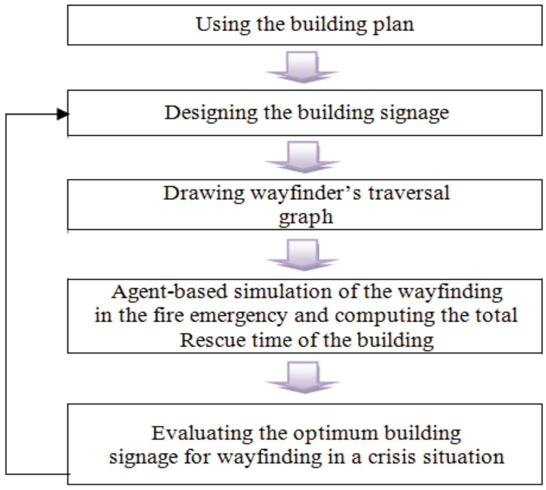

Fig. 5 The agent-based simulation of the wayfinding task

In these hospitals, as parts of the agent's states, the actual planned paths are marked as a directed graph with arrows [37], [38].The wayfinding agent observes the situation in the real world and learns about the building environment. Learning occurs when its observations do not confirm its belief about the reaching fire ways and their observable attributes [39]. Planning happens at every decision point where the agent has to select the next way to continue wayfinding via the optimal path to the destination. The agent's decision is based on the plan; it takes the path suggested by the planning program as the first step on the planned path to the destination. The agent would gain information from the building's signage which may be either directional or textual. By due attention to the cues and dynamic propagation of fire and smoke on the agent's interface, it would gain some information about its situation in the environment and its state would change.

When people are either familiar with the environment or have access to a map of the environment, the process of decision-making would be easier. This is not the case when finding one's way in an unfamiliar building; therefore, proposed a model of the preference as preferred directions within the agent's egocentric reference frame of Raubal [40]. This reference frame is represented through eight directions including: front, back, left, right, and the four directions in between.

One can allocate the orientation of the local reference frames to the nodes of the wayfinding environment in an arbitrary way. It makes sense though to adjust them in such a way that the number of axes pointing exactly to the bearings of "go-to" affordances is a maximum. This facilitates the process of assigning directions to the sign information connected to the outgoing paths. Fig. 6 shows the local reference frame for node 2, which is the decision point after entering the particular floor in the hospital. The signs "A,C", "A", and "B,C" are localized at the directions 0, 1, and 6.

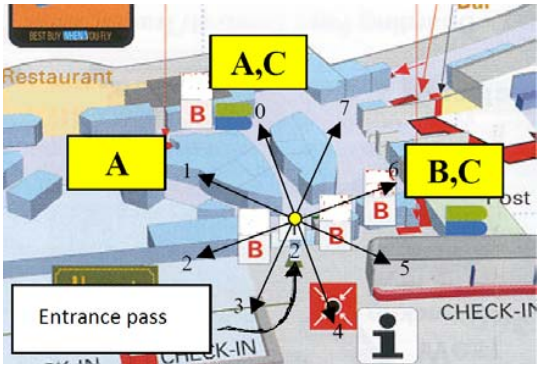

Fig. 6 Local reference frame for node 2-the decision point after Entrance pass

Agent 1 begins at the position 1 and point in time 1. Its goal is to find fire location. The list of spatial situations within the agent's state is empty because the agent has not perceived anything yet. The agent's previous position is assigned zero (unit0) and an arbitrary value for the incoming direction is specified. The agent has not made any decision therefore this value is also zero (unit0). The preferred directions of the agent are specified according to Fig. 7. The numbers the arrows point to stand for the cardinal directions North (0), North-West (1), West (2), South-West (3), South (4), South-East (5), East (6), and North-East (7). These are the directions within the agent's egocentric reference frame, therefore they correspond to front, back, left, right, etc. [4]. The ranking for the preferred directions is given as the numbers from 1 (highest preference) to 8 (lowest preference) inside the arrows.

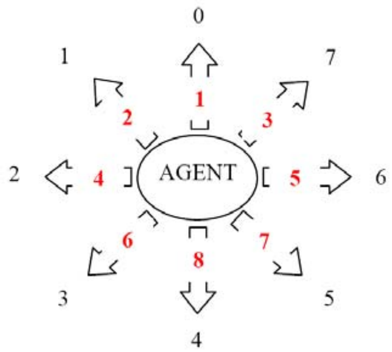

Fig. 7 Directions within the agent's egocentric reference frame and their corresponding preference Values [40]

The wayfinders' agents follows the information cues, makes decisions and moves in the virtual environment in order to reach the special ways of the building leading to fire location. Neither the ability to learn nor a lasting cognitive-map-like representation of the environment is involved in deciding upon and taking an action. The cognizing agent's decisions and actions are based on wayfinding strategies and common sense reasoning. Based on the knowledge in the world, the wayfinder takes a sequence of actions until the wayfinding task is completed.

When wayfinding agents reached the fire location, communicated to firemen and guided them to fire location in the optimum path for fire smoldering Agents use communication to negotiate with each other for collaborative action. One defining parameter for the design of a negotiation procedure is the radio range. To expand the search range for help beyond the immediate radio range, message forwarding strategies can be applied [41].

IV. Simulation

In order to clarify the concepts and methods used, we describe a case study that illustrates the situation in which our approach applies. It concerns the problem of wayfinding in a hospital in a crisis situation, specifically a fire emergency. The case studies for the proposed methodology is Moheb, Atieh and Shariati Hospitals located in in Tehran (in this research, is used the Moheb hospital picture for better comprehension).

In the first step, the hospital plans must be generalized in AutoCAD to abstract unusable details, because the excessive information occupies too much memory; then this generalized plan was imported in NetLogo environment.

In this simulation the environment is a complex multi-floor hospital with various exit ways such as emergency stairs and elevators. The hypothesis of the simulation is that in these hospital is only focused on second floor of them which the crowd populations is centralized in this floor and is ignored rest of the floors.

The nodes of the graph represent states of knowledge and current location in the wayfinding process, while the edges represent transitions either between views or between states of knowledge (Fig. 8).

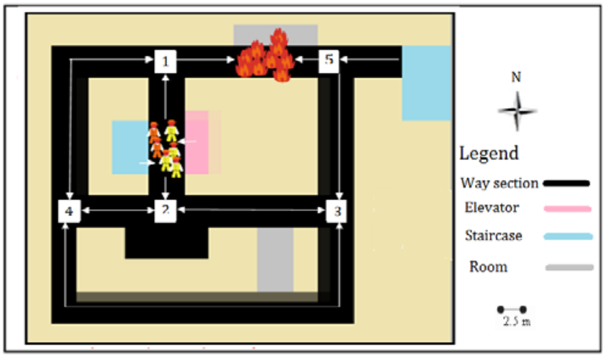

Fig. 8 The wayfinding graph in the hospital plan

In this paper, three kinds of agents are assumed including signs, fire and rescue team (including fireman and wayfinder). These agents are assumed to perform rescue operations that further detailed as follow:

Rescue teams are assumed to perform rescue operations by following three actions as 'Move', 'Search' and 'Rescue'. Rescue teams are assumed to belong to each fire room. Design of agent is based on agent's percepts, internal state, action search and move as follow:

A. Percepts

The agent receives percepts from the environment using an observation schema defined by the agent's immediate neighborhood of grid cells as shown in Fig. 9. This neighborhood is defined by the 8 neighboring grid cells occupied by the agent. Such a neighborhood can be referred to as a Moore neighborhood [42], Queen's case neighborhood [43], or simply as an 8-cell neighborhood [44]. The agent's environment was previously determined to be partially accessible. Within a raster environment, an 8-cell neighborhood provides a convenient means of representing limited access into the environment. The distance of this access is specified by the model resolution.

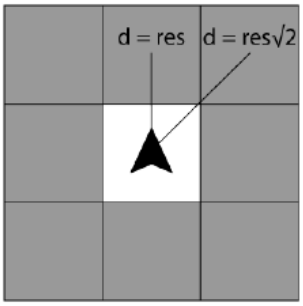

Fig. 9 Agent's 8-cell neighborhood and step distances defined by the model resolution

Some part of agent percepts programming section in NetLogo environment is detailed as follows:

```
for each neighbor
     if cue= [ flag right]
      [set heading 0  move-to patch-at 1 0 set
       heading 90 fd 1]
    else if cue= [ flag up]
       [  set heading 0  move-to patch-at 0 1 set
       heading 0 fd 1]
    else if cue= [ flag left]
       [set heading 0  move-to patch-at -1 0 set
       heading -90 fd 1]
    else if cue= [ flag down]
       [set heading 0  move-to patch-at 0 -1 set
         heading 180 fd 1]
```

B. Internal State

In this paper, the agent's internal state maintains properties for relative tract (the agent's heading relative to the environment) and an ordered list of previously occupied cells. Relative tract is used by the agent to determine the heading offset to each neighbor relative to the absolute heading of the agent. This allows the agent to choose the straightest path, distinguish between turns of different angles, or when necessary, maintain a constant heading.

Some part of agent internal state programming section in NetLogo environment is detailed as follows:

```
  set history history [this.x, this.y]
    for-each neighbor
     if [neighbor.x, neighbor.y] is-member of
       history
       return true else return false
```

C. Action 'Move's

Rescue teams go straight along a way until meet an intersection. In the intersection, rescue teams stop and determine the next travel direction. After that, rescue teams go straight again. In the intersection, by using signs and egocentric reference frame, the travel direction is selected according to associated weight of reaching goal. In this paper, action 'Move' is assumed to be performed every second. Action rules of rescue teams are shown in Fig. 10.

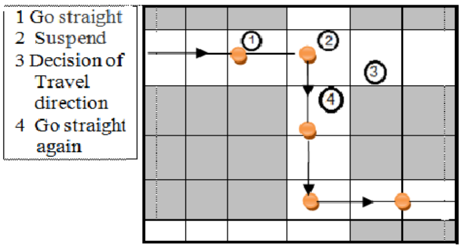

Fig. 10 Movement of Rescue Team

D. Action 'Search' by Wayfinders and 'Rescue' by Firemen

The rescue team searches for the rescue site in parallel with the moving action. Search areas are assumed to be 8 cells surrounding current position of the rescue team as shown in Fig. 11. If there are peoples trapped in a collapsed house within the search area that cell is determined as a rescue site and rescue operations are started. When there are multiple corresponding places, a rescue site is selected randomly.

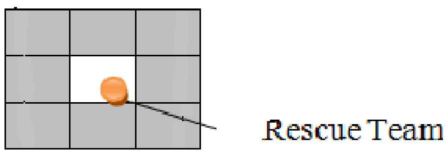

Fig. 11 Search Area

As for the rescue operations, wayfinder agents sent the his coordinates to firemen who are in radio range of wayfinder agents, thereby, firemen is beginning to reach themselves on wayfinders location.

Some part of agent seditions and actions programming section in NetLogo environment is detailed as follows:

```
to decide
     for each neighbor
         set neighbor.weightSum neighbor.value
     end
   set  nextCell  one-of  neighbors  with  max
   neighbor.weightSum
    do actuate
end

if sample? == true
     set pivot [this.x, this.y]
     set duration ticks + round normal-random 50
     10
     set sample? false
```

```
        do direction-sample
end
to direction-sample
     if ticks <= duration
        do actuate
     else
        set backTrack? true
end

to actuate
     set agent.heading toward nextCell
     set agent.x nextCell.x set agent.y nextCell.y
     do update
end
```

In order to simulate the wayfinding process and dynamic propagation of fire in the hospital building, the task in a simulation environment, NetLogo, is programmed, the different rescue times are computed and found the best placement and design of the cues and landmarks in the hospital wayfinding through the optimum building signage to take the shortest total rescue time in a crisis situation. In Fig. 12, the placement of clues is changed in four desertion point's neighborhood.

Fig. 12 Changing of signs area in Net Logo environment

The simulation results for three proposed hospitals have been compared in different designing situations (Table II).

According to Table II Ln and Rn are the cases with the worst signage design. However, with applying the quantity and placement modifications on it, the total rescue time has been reduced. Un and Dn are the situations with a sufficient quantity of signage in which the placement of signage has been improved. Mn is the case with the optimum placement of the signage. It can be observed from the results that in all of the signage design situations, the total rescue time have been reduced due to better placement of the cues and optimum determination of the quality and quantity of the signage.

V. Conclusion

In this paper, the decision making rescue team as agents for wayfinding simulation during firing building and designing of optimum placement signage is presented. These procedures explicitly consider the inherent dynamic and uncertain nature of circumstances requiring rescue operation. Therefore, they give rise to robust multi-agent-based rescue plans with lower probability of failure than paths determined otherwise, enabling faster and more efficient rescue of a building in the event of fire.

TABLE II
Units Comparing Total Rescue Time due to Signage Design based on Fig. 12

Different designing situations in the hospital	Total Rescue Time of the Building (s)		
	Moheb Hospital	Shariati Hospital	Atieh Hpsital
Left neighborhood (Ln)	125	112	103
Right neighborhood (Rn)	120	115	107
Middle neighborhood (Mn)	40	36	32
Up neighborhood (Un)	85	85	82
Down neighborhood (Dn)	93	90	87

This paper takes the spatial multi-agent simulation and determines an optimal plan to rescue operation in the building in the shortest time possible. Agent simulation for crisis management improves upon other simulation models that are concerned with numerical analyses of inputs or amounts of people and structures. This feature serves as an improvement to programs that only allow the agent to specify the occupants to follow the available paths considering the location of the fire or threat. The multi-agent-based system for crisis management is grounded on empirical data taken from real world experiments. The results show that the better placement of the cues and optimum planning of the quality and quantity of the signage lead to shorter rescue time from the building.

In all of the signage design situations, the total rescue time have been reduced due to better placement of the cues and optimum determining of the quality and quantity of the signage.

This research integrated elements of people's perception and cognition, therefore, focusing on how people make sense of their wayfinding environment. Our work showed that it is possible to provide a formal framework of the process of wayfinding that integrates parts of people's perception and cognition with information and possibilities for action afforded by the wayfinding environment such as a fire emergency. The wayfinding graph provides a discrete, dynamic model of knowledge and action as the wayfinding process progresses. Such a model, based on transitions within a finite graph, is computationally tractable and allows computer simulations of wayfinding that take into account knowledge in the world and knowledge in the head [45]. The model is of course only an approximation to the real process of human wayfinding and further work is required to determine how closely it approximates wayfinding in the real world. For example, color of signage and individual wayfinding criteria such as minimizing travel time or stress might be additional factors that need to be built into the model. Evaluations of the performance of the model also have been done in this research.

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