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DEVELOPING A MULTILEVEL DISTRIBUITING CROWDSOURCING SYSTEM FOR AIDING AND RESCUING TO OVERCOME WIDESPREAD CRISES

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На сьогоднішній день управління різними кризами в міських районах є одним з основних завдань суспільства через їх масштаби і обмежені ресурси. Використання натовпу для вирішення цих проблем було б правильним рішенням. Краудсорсинг, через велику кількість людей, різноманітності експертизи, поверхневого розсіювання і низької вартості, довго розглядався. Проте, управління такою кількістю людей для відновлення в кризовій ситуації тягне за собою багато проблем, в яких сучасні технології, засновані на інформаційних технологіях, в останні роки полегшують проблему.

У цій статті розроблена розподілена просторова система, що складається із сегментів і різних користувачів, яка може використовуватися для управління натовпом для вирішення проблем міського кризи. Система складається з декількох підсистем і декількох груп користувачів, які працюють на основі просторового краудсорсингу.

Пропонований новий сервіс є атомарним, що складається з керівництва по експлуатації, оперативного контенту і керуючого сегмента. Оперативний контент передбачає виконання простої дії. Рішення складних питань передбачає правильне поєднання простих послуг. Після ідентифікації кризової середовища з елементами системи, система розробляє відповідну комбінацію послуг для вирішення регіональних проблем, а потім розподіляє послуги відповідним рятувальникам на рівні регіону. Розроблений механізм розподілу та об'єднання послуг заснований на міждисциплінарному агентському середовищі.

Для оцінки, крім розробки сценаріїв тестування програмного забезпечення, система була протестована під час повені в Акале в 2019 році в провінції Голестан, Іран. Точність розподіленої систем була такою ж як її продуктивність, коли число користувачів збільшилася. Система також значно підвищила різні якісні показники, такі як втома рятувальника або затримка виконання завдання. Крім того, інноваційний метод оцінки краудсорсингу також виявив загальний показник успіху системи 44,5 %

Ключові слова: просторовий краудсорсинг, управління міськими катастрофами, просторовий розподіл, мультиагентне середовище, корпоративна ГІС

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1. Introduction

Governments face many challenges today that address rough problems in solving some of them. Basically, some of the challenges have features that require a lot of resources to solve. Solving some of the natural and social crises and issues arising from them are considered by this group [1]. Crises are usually large, and the control of their implications requires the use of a large amount of human and financial resources. Various solutions are available to control these crises. Using power of people who do not require much expertise or special sensitivity is one of the possible options [2].

Despite some negative points about the crowd of people such as low-level responsiveness or expertise, such remarkable privileges as high numbers, wide spatial coverage and high diversity of capabilities make them a special force to solve some of the crises [3] and other applications [4]. Therefore, it is possible to create a lot of forces with the unity of a few people's capabilities, and adapt it to the conditions [5]. Yet the important thing is how to manage and unite these forces to resolve crises at the level of a vast area.

The use of masses of people is largely seen in discussions on product quality and design ideas [6] or any specific products [7] or even special applications such as urban planning [8]. In these topics, the intellectual potential of individuals in an e-commerce space is shared. It is important that in such a space, there is no physical practice and no time urgency. However, the conditions required to solve problems in the crisis are different.

In a crisis area, many problems have been encountered in wide areas that should first be identified quickly. Popular forces with different capabilities in the region should be identified and lead to relief priorities based on their position and capabilities [9]. They should also be informed of the outcome of their actions, and if one of these people could not solve the problem, alternate or complementary persons should immediately introduced.

In this regard, a kind of information service is introduced in a crowdsourcing form. The service operates in the context of a compound system and, with the help of elements of this system, can quickly identify the crisis and identify the crowd of people in accordance with their expertise, capabilities and the standard crisis management guidelines, in order to solve the problems of the region.

Spatial crowdsourcing services are proposed with three main segments: Informative, activity and control segments which are connected to each other by a customized trigger mechanism. In the other words, each service segment executes next segment, as it is presented in Fig. 1.

Proposed spatial crowdsourcing services in a basic and simple form would be able to digest the complicated and long-aiding mission of a single individual injured from a critical situation to the safe or better status. Services may work on a variety of topics including recognition, rubbing, first medical aiding, carrying, feeding, sheltering etc. Each service at its primary segment guides a rescuer according to its capabilities and orders him the place to go. Then, it guides what to do and finally takes a confirmation whether the mission has been completely done. However, the main problem is related to managing issues. Managing many rescuers over disaster field at different situations with several skills in a central form is as difficult as finding the best arrangement of crowdsourcing services related to the injured ones.

First, the system detects the injured ones via the crowdsourcing services. Then, with the help of the same service, the system directs the appropriate rescuer to the rescue based on different parameters. The system is designed based on a multi-agent environment in which the mechanism of agents' search behavior is based on mathematical tools. These agents are designed to match the main objects of a crisis environment. The agents in the simulation environment mimic the various stages of crisis management, and after optimization, the final choice through the crowdsourcing service, inform the actual rescuers in the crisis environment.

The designed system can be used to manage widespread natural, clinical, social or even security crises. By employing the right combination of intelligent agents in the context of a distributed GIS, it can help large numbers of people affected by crises by employing large numbers of people. The method used allows the system to handle large numbers of users without any significant failing in the system performance. On the other hand, the system has high flexibility and is easily customized for a variety of crises. This flexibility is also used in the internal architecture and operation of the system itself. For example, the core service of the system is capable of performing different missions in different phases of the crisis.

2. Literature review and problem statement

Over time and with various crises, crisis management programs have been gradually developed through the examination of their data during a trial and error process, and interestingly, it provides an approximation of the overall structure of uniformity in various crises [9]. According to development of crisis management in the universities and scientific researches, it is now argued that all crisis management processes should follow the basic principles have been set out in the recent reference [10]. Accordingly, the crisis management doctrine should be comprehensive, constantly growing, danger based, Evaluable [11], collaborative, coordinated, flexible and ultimately knowledgeable and professional.

In recent years, the crisis management process has become very close to IT [12]. For example in 2014, the White House introduced a system called "Emergency Response System" (US) called "9", which aims to save lives altogether but also includes other goals such as overcoming social crises, helping the industrial, economic, etc. [13]. This project is partly an example of a system for doing something similar to crowdsourcing.

The project actually uses a physical network of computers on the first front. Any type of help request is registered at the center. The center will continue to arrange an army of dogs, human robots, automatic machines, automatic planes, and so on. In this project, information infrastructure is created through the development of a Wi-Fi network that is created in real-time in a crisis situation. The planes and wings of the model with the appropriate antennas in real time create the cover by flying the region at appropriate distances. Automated rescue tools simulate the crisis and operations environment in Simulink and Google Earth in three dimensions [14].

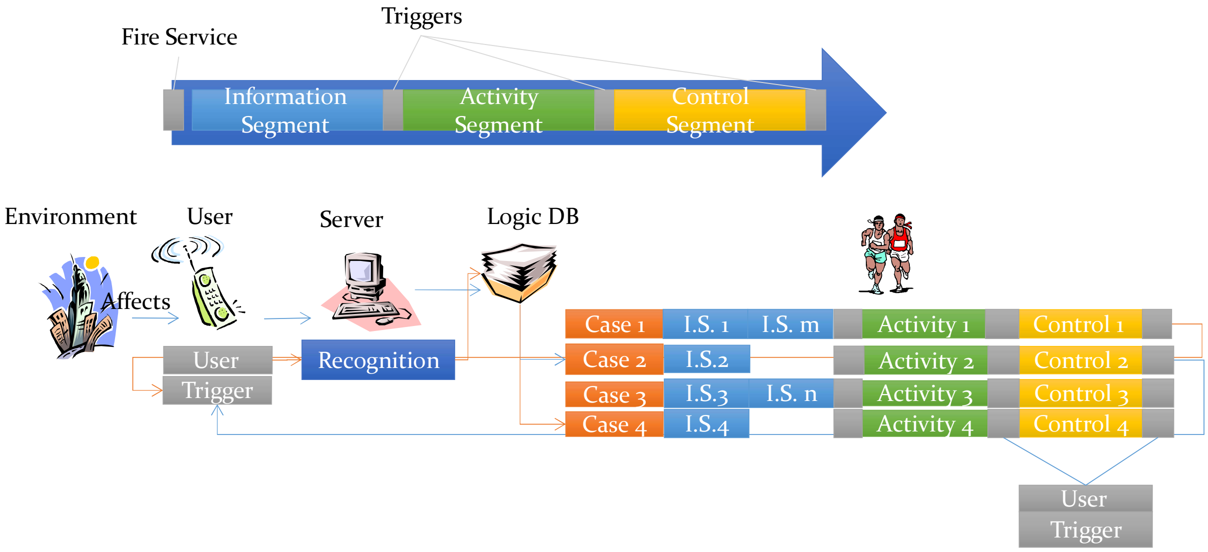


Fig. 1. Internal structure of spatial crowdsourcing services and decomposition of crisis problems to atomic simple solutions using crowdsourcing services

But the important thing in this project is the use of a centralized control system as well as the use of army and robot services. It is clear that such a solution is not in line with the existing conditions of the countries. On the other hand, the project did not use the power of the community at all. In the project, however, it is possible to focus on using people in a distributed system.

Perhaps one of the easiest things in the early studies is the provision of management services for a variety of peer-to-peer and voluntary services in the world. At present, organizations and public institutions and various government agencies around the world are providing voluntary services to the needy, however, around 30 institutions throughout the world [15], with the support of the people and the government, have seriously dealt with the trust of institutions internationally.

Voluntary systems, like ours, use the potential of the people. The only difference is that in this system the number of volunteers is much lower than the people in the community. On the other hand, the expertise of the people is less than the volunteers. Therefore, voluntary systems usually provide specialized and limited services. While it is a possibility to offer a variety of services with less skilled people.

In terms of service optimization and the optimal use of potential candidates [16], using systems such as those mentioned in this reference [17], many of which are non-spatial and do not utilize the power of spatial information processing correctly. On the other hand, the services provided by these institutions are largely physical and in general, are not close to the concept of providing services to people through the Internet. Also, in such structures, there is typically no full control over the volunteers and their actions [18].

Another topic that is somewhat close to our topic is social networking. Social networks can also unite different people to do the certain thing. These networks can be used to collect information and also to focus people on a particular problem. These processes can be considered particular types of crowdsourcing.

In recent years, with the expansion of social networks and geo-tagged data [19], this category has been considered by many scholars, along with content growth, related issues including big data analysis model [20], massive volume management, location, positioning without access to GNSS data, knowledge extraction from personal records similar to what has done in [21], service launching with minimal information and so on [22]. Although the challenges of social networking are also important in crowdsourcing, our system, functions differently from social networks. First, our goals are almost different from those of social networks. Second, in social networks, processes are mostly human-based, while in our system there is some kind of intelligent automation.

In some researches such as [23], the complementary role of social networks and Volunteered Geographic Information in the field of spatial data production and their processing or accuracy [24] has been pointed out. Rather than quality and confidence level in such data [25], at least in times of crisis and emergency, when access to other spatial information is not possible, it is a good source for processing [26]. Aside from the simple and basic structure of such information, it is possible to point to discussions related to the analysis of spatial data in these social networks, such as [27]. One of these cases is the extraction of a humanitarian model in times of crisis and unexpected incidents. This issue can be considered along with the investigation of clusters obtained from spatial information of social networks [28]. In the same vein, these issues are among subjects that, in addition to privacy issues, have been already added to crisis management information systems topics [29]. In fact, such issues have also been of interest to us. Accordingly, there are similar analyzes of this issue in our work and similar experiences can be used.

On the other side, crowdsourcing started with an almost identical past. Crowdsourcing for the first time was used to describe outsourcing of products to the crowd [6]. The word “crowdsourcing” contains two concepts of outsourcing and baggage of crowd [30, 31]. The crowd could bring their money [32], ideas [33], works and experiences to receive mutual benefits. The crowd will satisfy some of their demands including professional abilities, social or economic benefits [30]. Accordingly, let’s use a variety of crowdsourcing services in our system.

Crowdsourcing could be recognized in two phases, sending a given problem to crowd and then absorbing their contribution in an open call to solve it! Then people offer their solution in that open session. Finally, solution is find, which would receive a prize or just satisfy their cognition intellectually. Contributors by different knowledge and experts would be known or unknown to crowdsourcers [34]. This process is almost the backbone of our system. That is, with crowdsourcing, information of community problems is collected. The system then suggests problems to the appropriate people to solve them. Although rescuers are not supposed to be rewarded, their successful missions are recorded and increase the individual rank in the system. Nevertheless, most crowdsourcing applications are not based on location-specific data; however, in the context of our topic, spatial data is the main focus of research [35].

This attitude makes the common thinking about collecting ideas and focusing intelligence on crowdsourcing towards other activities tends. Nevertheless, the interesting thing about our subject is its similarity to the volunteers for the content provider. In other words, while in the matter of crowdsourcing and Ambient Geographic Information, the data producer is not so important [36], in our subject matter, as well as Volunteered Geographic Information, the producer of spatial content is of particular importance.

However, in spite of the conceptual proximity of topics such as social networks, volunteers and crowdsourcing to crisis management, the appropriate and practical integration of these issues has not yet been developed in practice. Although each of the issues presented alone seems to have good potential, these potentials need to be developed in line with the standard crisis management and rescue and relief plans. On the other hand, given the specific circumstances of the crisis, how to define and apply technology-based services is not so simple. Accordingly, these services must be designed in such a way to maximize the ease of use and taking into account the general conditions of the crisis area.

3. The aim and objectives of research

The main aim of this research is to design a system to use potential of the people to solve crisis management problems via the spatial crowdsourcing services.

To accomplish the aim, the following tasks have been set:

– create a highly flexible spatial crowdsourcing service;

– manage this service, design an enterprise multi-user Geospatial Information System;

– implement very flexible user interfaces for each user. Indeed, the processes required for crisis management are divided between these different users;

– the most important interface is the interface between the system, the rescuers and the rescuee. Let's also design and implement this interface with high flexibility and customization. By increasing the flexibility of the system and its interfaces, it is possible to easily use the system to manage any type of crisis.

4. Solution

Simply, our proposed solution is based on the use of the spatial crowdsourcing service in the context of a distributed Geospatial Information System. In other words, the solution has been distributed in different elements of the system, their operations and their interactions.

The system operates in a very simple way. First, the status of the crisis environment is identified. In this regard, let's design a user interface that works with our proposed spatial crowdsourcing service. Interestingly, both the interface and the service perform different missions. This is due to their flexible structure. Regardless of the flexible mechanism of the service and user interface, the user uses this interface to enter the crisis environment conditions in the operation class of database (Fig. 6, position 7). Let's note that the user would be an injured person asking for help, or a rescuer, or a user who is moving in the crisis environment just to identify. For this purpose, two combo boxes of this interface are connected to two fields of the operation class and receive domain values from these fields. These two fields determine the type and status of the crisis. There are also two other fields in the operation class to store numerical values of the crisis. In this way, after determining the state and type of crisis, the user can enter numerical values for them. There are also two other fields in the same class that let the user to upload favorite additional images via interface as in Fig. 13, *c*. In order to prevent the database from slowing down, an add-on type has been used.

Then a regular chain of suitable people, who are willing to help, will be redirected to the required places by the system. In this regard, the system tries to resolve the problems in the crisis region as far as possible and, after each stage of relief, re-establish the status of the region. These processes all relies on the new proposed service, different subsystems and multiple system users (Fig. 2).

Therefore, the main structure of the system is first introduced and then users of this system are introduced as the main system elements. The role of each of them in the crisis management cycle is briefly outlined and then, to better understand the performance and interaction of these users, the conceptual model of system's spatial database core and the status of our proposed service are introduced. After expressing how the various components of the model function, let's look at the most important part of the system which is responsible for the allocation process. At the end, the profile of the different user's interface will be expressed and how users interact with those interfaces.

5. System Architecture and Implementation

In the following parts, different parts of the system will be considered. Their roles and interactions between the different parts and their relationships to the overall solution will be considered.

5. 1. System Users

The core of the system is a spatial database that is distributed with several children at a wide spatial range. The main reason for this is the creation of a Data Structured to lighten the burden of data storage in the system, adhere to the Spatial Data Infrastructure constraints and distributed Processing of different users. There is a continuous updating process between the parent and its offspring. The main task of this core is the storage of all spatial information related to the objects of the crisis environment. On the other hand, much of the required computations and analyzes, are implemented through the tools in the database, including stored functions, views, and triggers inside the same kernel. Fig. 3 displays the schematic of system elements and their general connections.

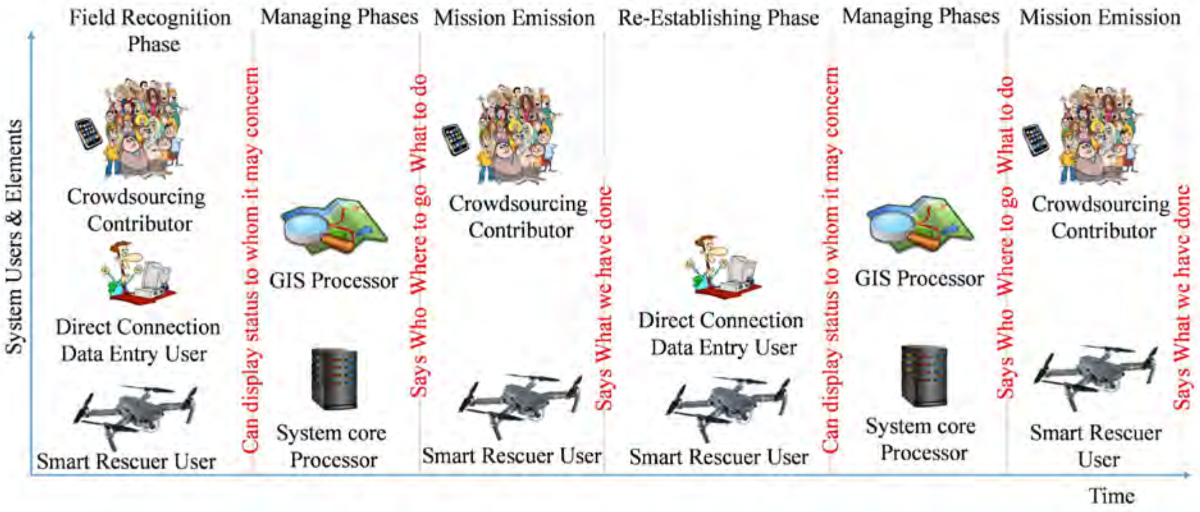


Fig. 2. A simple schema of the steps that system components take to manage services over time

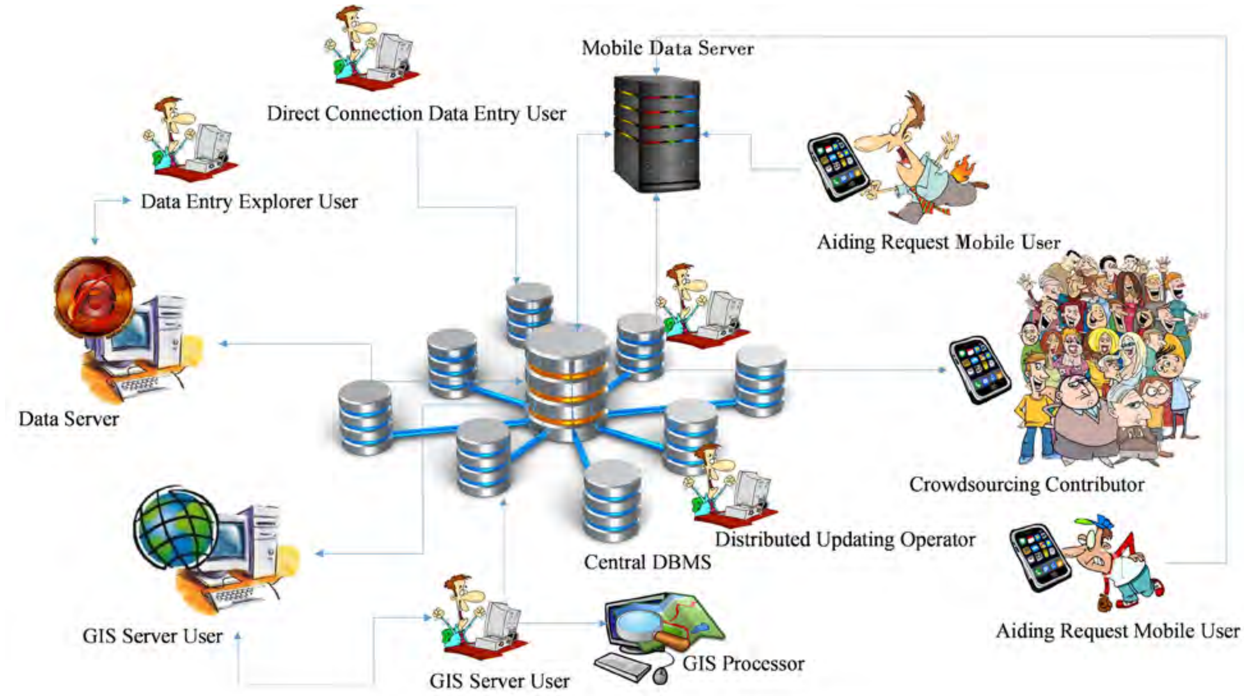
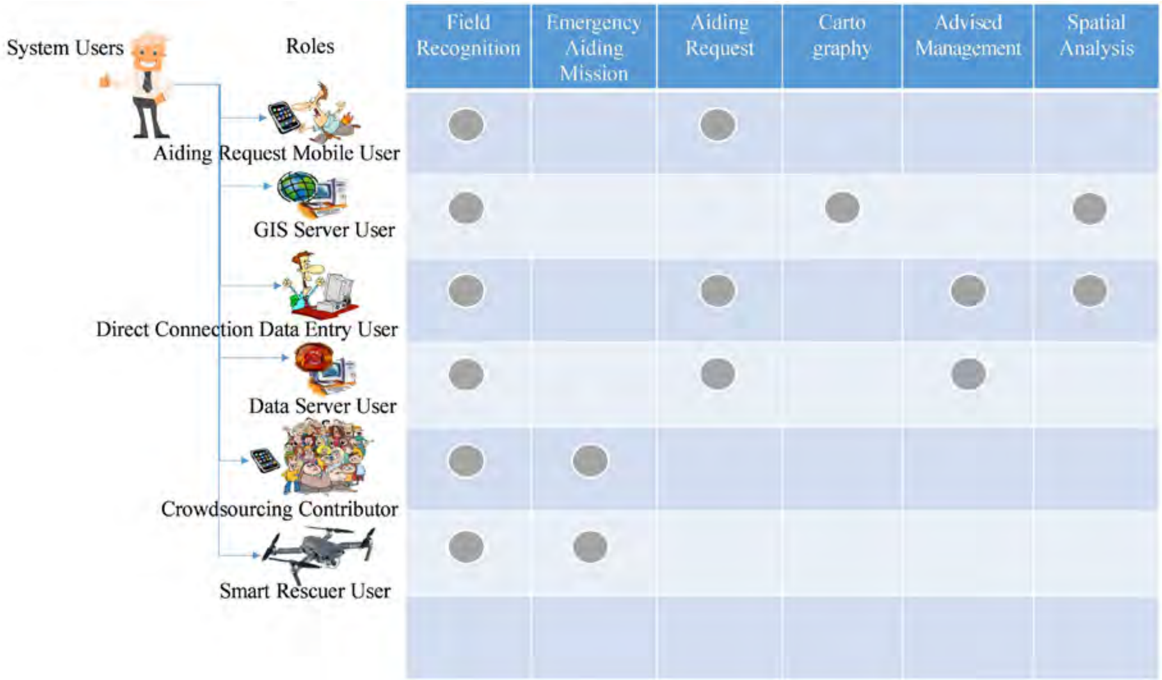


Fig. 3. Schematic of system elements

A spatial data processing unit as the central DBMS performs spatial analysis by connecting to the child database which encircles the central database. This is because of the release of central processing resources for critical operations. Thus, non-spatial processing takes place at the core of the spatial geodatabase and spatial processing in this unit. Apart from these two units that perform almost automatic processing and storage of information, other system elements typically have the task of communicating with the original users.

This system covers various users and each user can have different roles in the system. The main roles in this system include status identification, rescue and relief operations, help requests, cartography, supervised management, and spatial analysis. These roles form the core elements of crisis management. Fig. 4 shows the main users of the system and their roles. Records represent different system users and columns representing six different roles of the system. This graph states that the direct user has 4 different roles in the system and is somehow the most important user of the system. Also, all system users can have an identifying role, except that they perform this task in a variety of ways.



System Users / Roles	Field Recognition	Emergency Aiding Mission	Aiding Request	Carto graphy	Advised Management	Spatial Analysis
Aiding Request Mobile User	●		●			
GIS Server User	●			●		●
Direct Connection Data Entry User	●		●		●	●
Data Server User	●		●		●	
Crowdsourcing Contributor	●	●				
Smart Rescuer User	●	●				

Fig. 4. Main system uses and their potential roles

If the main cycle of crisis management involves the process of identification, data acquisition and management, spatial analysis, cartography, crowd guidance, assistance and re-monitoring, the system's various elements, together with its various users, cover this cycle. Fig. 5 shows the various stages in the crisis management cycle and system user that performs that stage.

5. 2. Central DBMS structure

In the core of the system, the geodatabase, the crisis environment is simulated using relational classes. Each of these classes is somehow connected to the actual objects of the crisis. Some classes have a consistent and non-intelligent behavior and simulate only objects that have an interactive role, while others are smart. At the center of this class is the "Operation" class (Fig. 6, position 7), which is equivalent to the spatial crowdsourcing service.

This class is completed in conjunction with the user class (Fig. 6, position 11) and extracts the required parameters from classes such as Request (Fig. 6, position 2) and Expert (Fig. 6, position 9). Allocation class (Fig. 6, position 10) is a communication center designed for recording communications between other classes. The User class (Fig. 6, position 11) is a parent of two classes with smart behaviors, Rescuers (Fig. 6, position 14) and Requests (Fig. 6, position 2). These two classes simulate and execute intelligent behavioral search through the built-in mechanisms. The search environment employs two types of Topology (Fig. 6, position 13) and Raster space (Fig. 6, position 16) in searching for smart agents. The Position class (Fig. 6, position 18) generates the position of all the objects in the environment. Of course, this class acts smartly, with its own mechanism on the bank of points, produces instantaneous location for each requestor.

Specification class (Fig. 6, position 8) is the main supplier of the parameters required and observed on the service. Resource class (Fig. 6, position 14) is one of the non-smart and auxiliary classes of the environment that puts all kinds of resources (Fig. 6, position 20) required by the User's class into consideration, and adjust their parameters accordingly to the new inventory. The Captions class (Fig. 6, position 1) has nothing to do with the main object class, but just to customize the display method and the instant content of the mobile users' GUI.

Various methods have been used to perform smart functions or interactive behaviors between classes. The main parts of intelligent behaviors or interactive behaviors were designed and implemented as functions in the database environment. For this purpose, effectively, views, stored functions, and triggers were used. Although the use of views is preferable to other developmental mechanisms, its structure is more suited to simpler computational mechanisms such as the calculation of direct parameters. More complex behaviors, such as smart search in relief and rescue agents, were simulated by combining triggers and stored functions.

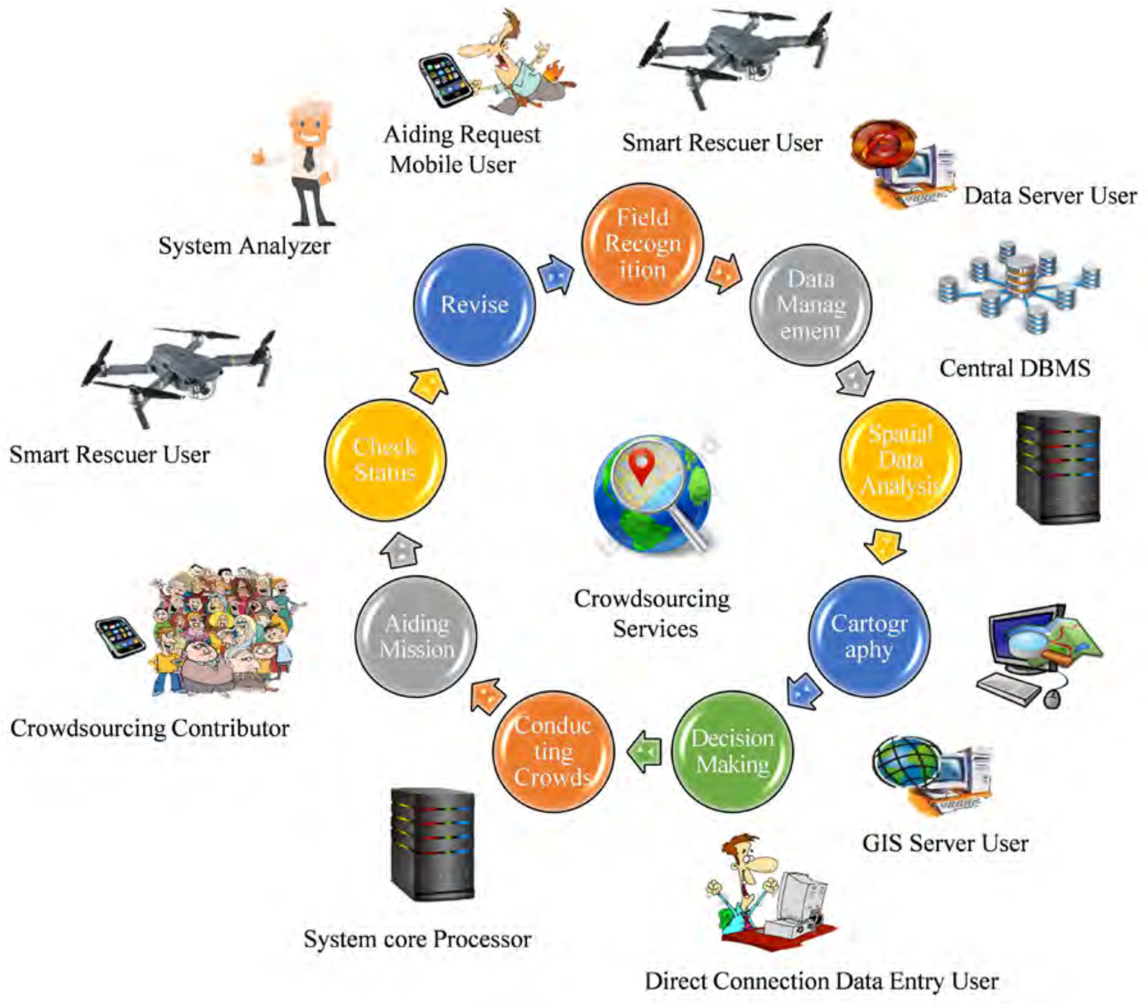


Fig. 5. Various stages of disaster management cycle and suitable users that could do the task

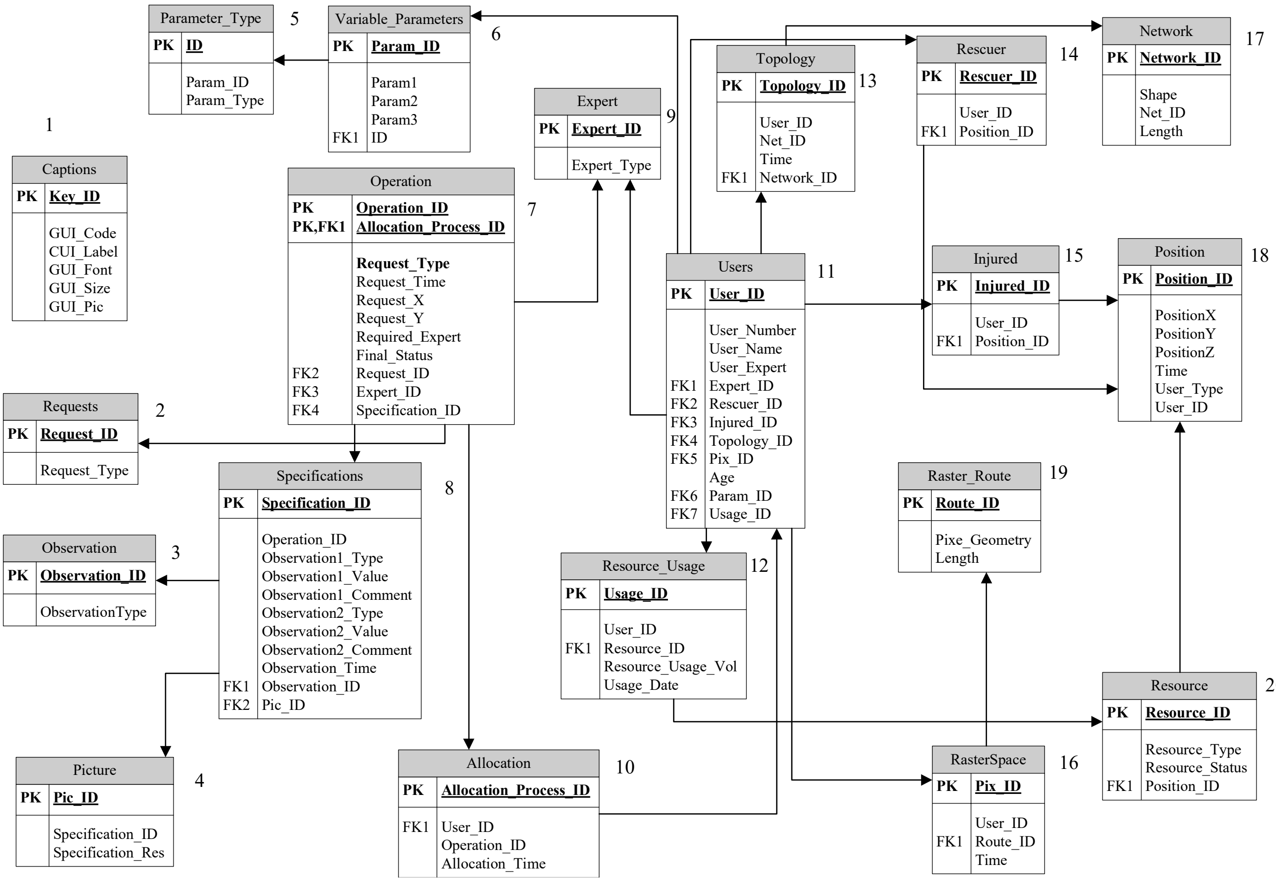


Fig. 6. Relational database of system main objects

The system mainly uses multiple data sets. The first group is the infrastructure classes and networks in the environment such as roads, electrical distribution nets or water distribution networks. These data are provided by government agencies and institutions, but some of their descriptions may be updated by system users.

The second group is related to rescuers. This data includes the static and dynamic characteristics of the rescuers, some of which are recorded by the rescuers themselves (on registering time) in the system (Fig. 6, position 14), and the other part is automatically updated by the system in the database.

The third group is related to the rescuee in the environment (Fig. 6, position 15). This data is either recorded in the system by the injured themselves or other users enter it to identify their environment.

Finally the fourth group of data is related to resources and their status in the environment. This data must either be updated directly using telemetry mechanisms or simulated by the system operation.

5. 3. Allocation system mechanism

As system starts, people first install an application on their smartphones. In the sequel, all popular users, whether they want to participate in rescue and relief process or those who are not interested in helping, sign up through the same application in the system, and register their features and abilities in the implementation of various relief operations in the system. With the onset of a crisis or incident, the application installed on smartphones interacts with the central core of the system, automatically changes its interface and ready to receive assistance requests.

At this stage, all users who need help, via their user interface and the crowdsourcing services, as simple as possible, register their requests. At the same time, some complementary information such as an image that describes their situation, and the position of the request is automatically transferred to the center via the crowdsourcing service.

The Geospatial information processing center after receiving the information of the request points, first specifies the type of operation to be performed at each point and, on the other hand, by continuous monitoring of all the users who are present in the scene, based on the features and capabilities and of course their location, select the most appropriate people for the rescue and relief operation. Then, by sending the crowdsourcing service to the selected users, guide them to the desired position and specify the type of operation to be performed at that point. At the end, the service asks the rescuer user to determine whether it has completed its operations or needs help or has completely abandoned it?

If the operation has been completed successfully, the system send other people with the other needed abilities to the location, but if the rescuers hasn't done the mission or need additional help, system proceeds with alternative rescuers or assistances in the same specialty.

The system receives relief requests in the next phase. To solve each request, a chain of activities and individuals may be required, while each crowdsourcing service, according to our design type, performs a simple activity by one person. Therefore, it is necessary for the system to divide a complex problem into simple and small parts, and then offer a suitable chain of simple crowdsourcing services to the most suitable people on the field. But the question is how can to combine services and how can to select right people for services?

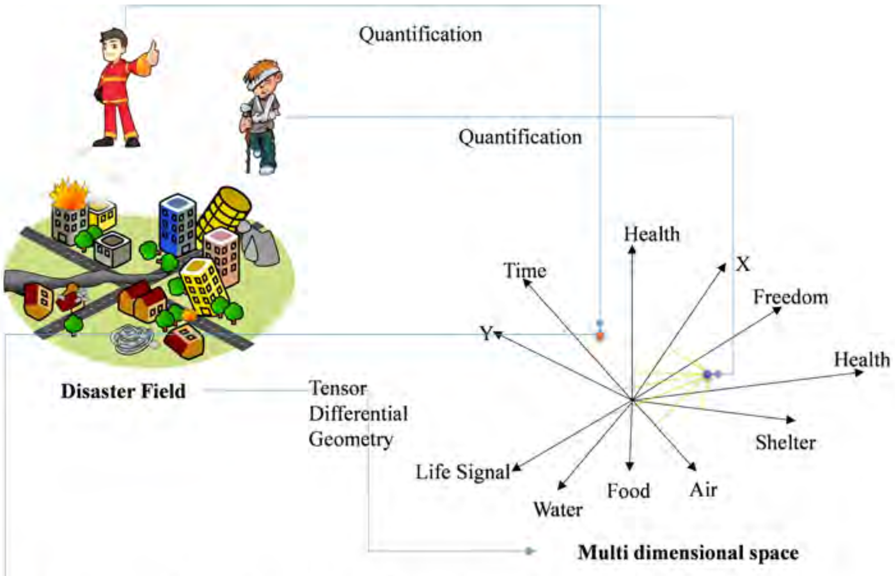
For this purpose, a multi-purpose environment was used. The main objects of the crisis environment, including equipment, resources and infrastructure as objects and rescuers and injuries, were simulated as intelligent agents in the crisis environment. Each of the objects and smart agents connect to their real objects in crisis environment. In this way, intelligent agents in the simulated environment interact with themselves and the objects of the environment find the best combination of crowdsourcing services and find the most appropriate agents that must perform these services. When intelligent rescuer agents find their appropriate services in the simulation environment, the system transmits the selected service to the right person in real crisis environment.

In the design of multi-agent environment, the basic structure of the BDI (Belief Desire Intention) agents was used. Beliefs in our agents are what the agents think or receive from the environment. In our research, the rescuer agents' beliefs are a list of the injure agents and their positions, characteristics and type of needs in the environment. The rescuer agents' intentions are what they want. At this point, determining the priority of relief missions to the injured agents is the rescuer agent's intent. Obviously, the priority of relief mission is determined on the basis of the static and dynamic conditions of both agents and their environment. In the end, the main choice of the rescuer agent from the list is the relief agent's desire.

Regardless of the BDI smart agents' specifications, there are two main behaviors for them. Perception that it is called at each recurrence and causes the beliefs of the agent to be updated. Another behavior is plan. Each agent has a set of plans to achieve its intentions. These plans may be permanent, instantaneously or changing according to conditions.

Fig. 7 represents the thinking process for a rescuer agent. Perception (Fig. 7, position 1) receives environment conditions in the form of status vectors. Achieve segment (Fig. 7, position 2) indicates whether the previous mission has been done, Fig. 7 (position 3) removes the previous mission from the list of missions, Fig. 7 (position 4) confirms the new mission (intention), Fig. 7 (position 5) selects the new mission or the new intention based on the desires list. Fig. 7 (position 6) performs the plan selection for the confirmed intention, Fig. 7 (position 7) is the execution stage of the plan, Fig. 7 (position 8), determines the continuation of the selected plan, and Fig. 7 (position 9). Specifies that at this stage of implementation just one plan must be made or multiple plans?

Let's implement these mechanisms with a simple mathematical model for the agent. For the main classes of the crisis environment, let's include rescuers, injured ones and resources vectors based on common characters as in Fig. 8.



$$\vec{V}_{rescuer} = r_i\vec{x} + r_{i+1}\vec{y} + r_{i+2}\vec{t} + r_{i+3}\vec{d} + r_{i+4}\vec{s} + r_{i+5}\vec{a} + r_{i+6}\vec{w} + r_{i+7}\vec{f} + r_{i+8}\overrightarrow{sh}$$

Fig. 8. The state vector of a rescuer's position in the multidimensional space of the crisis

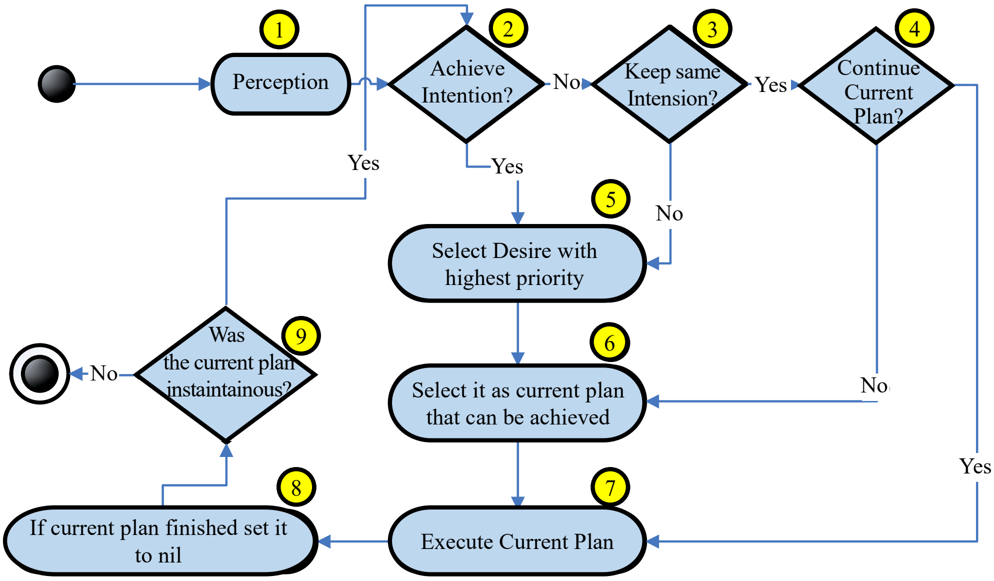


Fig. 7. Thinking process based on primary perception

So for each class of agents, let's have a multi-dimensional vector like:

$$V_{rescuer}\left(x,y,t,d,s,a,w,f,sh\right)= =\begin{cases} r_i\vec{x}+r_{i+1}\vec{y}+r_{i+2}\vec{t}+r_{i+3}\vec{d}+r_{i+4}\vec{s}+ \\ +r_{i+5}\vec{a}+r_{i+6}\vec{w}+r_{i+7}\vec{f}+r_{i+8}\overrightarrow{sh}|r_i\in R \end{cases}.$$

The components of this vector include features, positions, vital signs, and the like. This vector is the constructor of agent's beliefs.

If to take t as the start time of an interrupt from the program, then:

$$\overrightarrow{I_a^t}=f\left(R,A,T\right)$$

and

$$\overrightarrow{I_f^t}=f'\left(R,A,T\right),$$

where $\overrightarrow{I_f^t}$ represents vector of rescuer agent's Desires, it means set of the injured who can help them, $\overrightarrow{I_a^t}$ indicates plans or activities should be done for each injured, $f(R, A, T)$ is the function that create agent's intention and includes R as rescuer matrix, A as injured or aiding request matrix and T as tools or resources matrix.

$$\overrightarrow{I_f^t}_{m\times 1}\times\overrightarrow{I_f^t}_{1\times n}=M_{m\times n}^t, \tag{1}$$

In equation (1), $M_{m\times n}^t$ is the matrix which its elements are $\left(Injured_m, Activity_n\right)$ it means the certain activity which should be done for given injured. Val function acts on:

$$g\left(\alpha_s,\beta,p_g,p_a,p'_g,p'_a\right)= =\left|\frac{24.15\alpha_s\beta+3.73}{\left(p_g-p'_g+0.12\right)\left(p_a-p'_a-0.07\right)}\right|, \tag{2}$$

in which α_s is the fatigue status of the selected rescuer, β represents the priority of rescuing mission, p_g, p_a stand for spatial and aspatial position of rescuer in computational space, p'_g, p'_a represent spatial and aspatial position of aiding request or injured ones.

Likewise, $p_g-p'_g$ and $p_a-p'_a$ are calculated as (3):

$$p_g-p'_g=\left(\vec{V}_g-\vec{V}'_g\right).\left(\vec{V}_g-\vec{V}'_g\right), \tag{3}$$

in which $\vec{V}_g$, $\vec{V}'_g$ are the vector position of rescuers and aiding request. The coefficients and constants of the model are also obtained by nonlinear solution at 9 test points based on Analytic Hierarchy Process method.

Function f, Simply generate a matrix of m number of rescuers, n number or injured or aiding requests:

$$f_i\left(R_{Rescuer},A_{Injured},T_{Resource}\right)= =Row_i\left(\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn}\end{pmatrix}\right), \tag{4}$$

where

$$a_{mn}=\begin{cases}1,\ Request_{Type}=Rescuer_{Type}, \\ 0,\ Request_{Type}\neq Rescuer_{Type}.\end{cases}$$

The final output of the rescuer agent is the final decision taken to help a particular injured agent among other injured agents. Each action subsequently includes consequences. The consequences of this operation, such as the removal of environmental resources are sent to the environment via function g. This structure was deployed in the database development Environment and a programming language.

As the system starts in t=1 s, the optimum selection is done from the matrix (5):

$$M_{m\times n}^{t+1}=g\left(M_{m\times n}^t\right). \tag{5}$$

It means a member with a maximum score is the best choice for the rescuer agent. The row number is the selected rescuer, and the column number indicates the action to be taken for that injured or aiding request.

Also, a function in the form of the equation (6) updates the fatigue parameter of each agent:

$$\alpha_s^t=\alpha_s^{t-1}+7.157\left(p_g^{t-1}-p_g'^{t-1}\right)+1.47\left(p_a^{t-1}-p_a'^{t-1}\right), \tag{6}$$

in which α_s^t is the fatigue of a given agent in time t, p_g, p'_g, p_a, p'_a, stand for rescuer and rescuee agent spatial position, and rescuer and rescue aspatial position in time t–1.

6. System Implementation

As previously mentioned, the system covers a wide variety of users. Each user class uses a specific interface that meets its requirements to communicate with other system parts. A number of manager users, depending on their type of activity and their knowledge, are simply connected through the web browser. These users manage the rescuers or requests in specific situations. Fig. 9 shows one of these users' menus to insert a new relief request in non-spatial mode.

نام کاربر ثبت	توضیح اولیه	نوع درخواست اولیه	تخصص مورد نیاز	نوع اضطرار فعلی	کیفیت مسئله	طول جغرافیایی	عرض جغرافیایی	ارتفاع	زمان ثبت	تصویر شناسایی	عکس دوم	نام کاربر عملیات	وضعیت عملیات	
مجید	تست	گیرکردن در آوار	کمکهای پزشکی اورژانسی	گیرکردن در آوار	تست1	0	0	0	PM 9:43:46 9/24/2017	jpg.201709242143465077	jpg.201709242143467182	حامد	ارجاع به بعدی	ویرایش
مجید	تست2	گیرکردن در آوار	امدادگر عمومی	گیرکردن در آوار	تست4	49.7009483333333	34.10564	1723	AM 9:45:57 9/25/2017	jpg.201709242145568166	jpg.201709242145569983	حامد	انجام شده	ویرایش
مجید	test	نیاز به انتقال	امدادگر عمومی	[illegible]	test2	49.7155513	34.1002158	0	PM 5:30:38 10/4/2017	jpg.201710041730381743	jpg.201710041730385054	حامد	انجام شده	ویرایش
حامد	برای اطمینان	نیاز به دارو	کمکهای پزشکی اورژانسی	وضعیت جسمانی بد	[illegible]	49	34	1800	AM 12:00:00 10/5/2017			حامد	انجام شده	ویرایش
حامد	جهت صدور	نیاز به انتقال	کمکهای پزشکی اورژانسی	نیاز به آب و غذا	[illegible]	49	34	1805	AM 12:00:00 10/4/2017			حامد	انجام شده	ویرایش
حامد	کمالی	نیاز به جابجایی سنگین	کمکهای پزشکی اورژانسی	[illegible]	[illegible]	49.7301427	34.099358	0	PM 9:40:09 8/14/2018	jpg.201808142140087743	jpg.201808142140088991	حامد	ارجاع به بعدی	ویرایش
هوشنگ	[illegible]	وضعیت جسمانی بد	امدادگر عمومی	وضعیت جسمانی بد	[illegible]	49.378	34.0012	1850	AM 12:00:00 9/11/2018			مجید	ارجاع به بعدی	ویرایش
حامد	[illegible]	نیاز به انتقال	کمکهای پزشکی اورژانسی	نیاز به انتقال	[illegible]	49	35	1750	AM 12:00:00 9/12/2018			حامد	ارجاع به بعدی	ویرایش
هوشنگ	[illegible]	وضعیت جسمانی بد	امدادگر عمومی	وضعیت جسمانی بد	[illegible]	49.5	34.897	1852.5	AM 12:00:00 9/15/2018			مجید	جدید	ویرایش
مجید	[illegible]	گیرکردن در آوار	امدادگر عمومی	گیرکردن در آوار	[illegible]	48	34	1758	AM 12:00:00 9/26/2018			حامد	جدید	ویرایش

Fig. 9. Web browser user menu to simply insert new requests or enforce rescuers

Among the other system users, the SDE user is connected directly to the geodatabase. With access to all spatial and descriptive information, the user can control all of the operations in the system and is in some way a system administrator at the command center. In addition to the capabilities of other users, this user can access spatial classes with a variety of spatial processing with the help of tools, functions, and spatial queries.

For example, all users who have remained constant for a significant period of time before and after the crisis and have not made any move can be identified as possible points for rescuing mission. Fig. 10 shows these points and the time of stopping since the crisis occurred.

In a similar way, it can monitor the status of resources available at the service stations in real time, in terms of remaining percentage or capacity, in order to compensate reduced resources. Fig. 11 is an image of the software, in which the residual amount of water, medicine, food and equipment is displayed to logistics managers.

Fig. 10. Designed analysis for finding system users with long stopping time since crisis occurred

Fig. 11. Displaying the remaining amount of the critical resources in the graphical user environment

Similarly, it can categorize rescuers according to the amount of their fatigue in different parts of the city, and locate it on a map or creates crisis density map. Also, a map of the type of needs in the city with proper symbology, along with other complications.

Another system subscriber is the user of the map server on the Internet. This user also has the ability to identify, limit information entry and display of cartographic information, and, of course, has a very limited tool for analyzing spatial information. This user can use the services directly on the web and may have a client-side tool or just use the web browser. Fig. 12 shows an overview of the region's different needs and requests with the satellite background image along with main roads.

But perhaps the main user of this system is the crowd of people, which is almost entirely connected to the crowdsourcing services. Different crowdsourcing users need to have the same, simple user interface on their smart phone to work in this system. This GUI, who uses the Open Street Map service as a background map, is the main interface of the crowd. This GUI and the subsequent crowdsourcing services have three main roles. The first role of the interface and service is to register aiding requests. Two combo boxes are used to register the application, the values of which are determined by the original server. In other words, system administrators can adapt domains of these combo boxes to suit the type and the severity of the crises. Fig. 13 shows crowd mobile user interface.

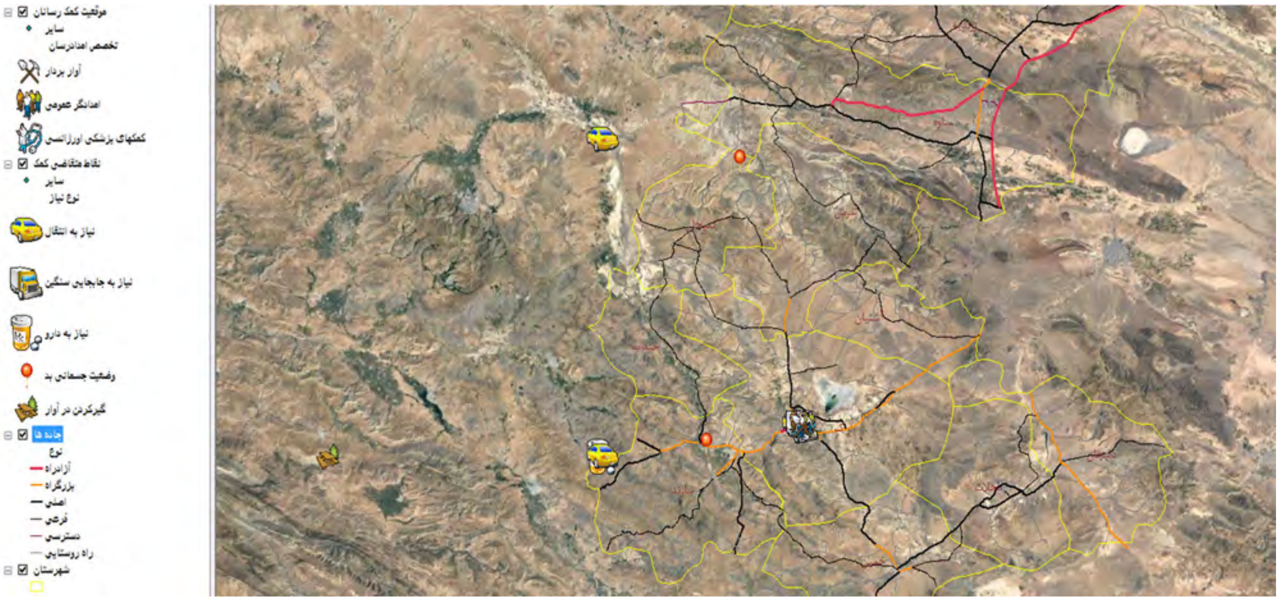


Fig. 12. A GIS server user, server side, in a web browser with main requests' types

192.168.1.22:8080

حامد عیوضی
شماره تلفن 09012677864

نوع درخواست اولیه: گیرکردن در آوار

تخصص مورد نیاز: امدادگر عمومی

نوع اضطرار فعلی: گیرکردن در آوار

a *b* *c*

Fig. 13. Crowdsourcing mobile user interface and its components: *a* – primary page of interface and main task selection; *b* – task page of interface, selection of status by predefined combo box; *c* – capturing extra information by taking a photo of the surveyed problem

Using texts to reports situations in crisis field would be difficult therefore it is possible to use icons in GUI instead of using simple buttons with text labels. In addition to the combo boxes, two additional parameters are also taken by this interface, which are proportional to the type of selected combo box cases that express their quantity.

The second role of this interface is the crisis field identification. That is, users can report the status of critical areas in the crisis field instead of applying for help. Users can also upload two images for this purpose. The third role of this interface is to guide the rescuers for emergency missions. In other words, the system first identifies the critical users with aiding requests, and then suggests them to the appropriate rescuers based on the method described above.

A rescue user comes in contact with a list of applicants by connecting to the system and receiving a payroll service. Rescuer controls the list and selects the right item among them, then system guides him with its map menu. After reaching the site, if the operation is successful, rescuer taps the status key and informs the system that the request has been successfully completed. Otherwise, with the touch of the Suspension key, the system will realize that it needs to send other rescuer users to this point.

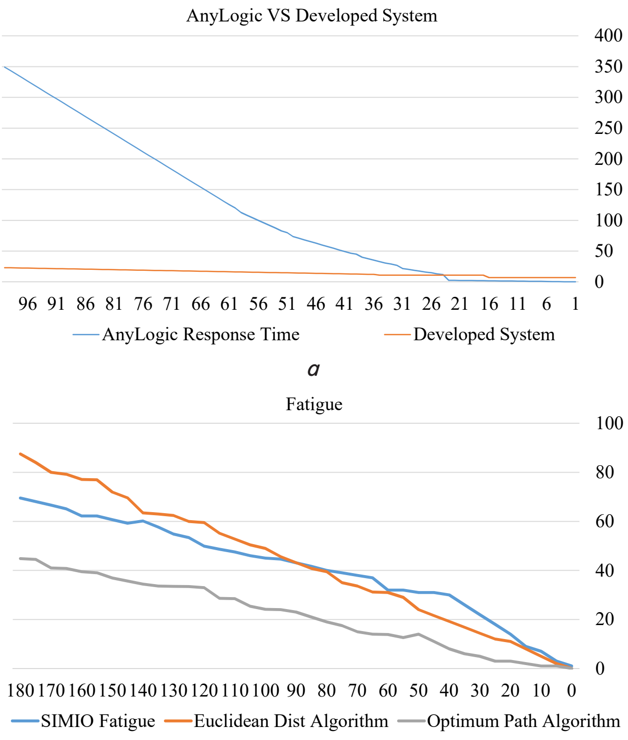
7. System Evaluation

In order to evaluate system performance, some simulation methods and scenarios were defined for monitoring and controlling the performance and accuracy of different parts of the system. In these scenarios, instead of controlling the whole system at a time, various parts of the system were finely examined.

In the first scenario, a simple competitive multi-agent environment was designed in AnyLogic [1]. Further, agents were programmed to touch some constant points as injured in a network space, among which those with more touching won. In order to test the system overall speed, the agents' number were gradually increased in both AnyLogic and developed system. As shown in Fig. 14, *a*, the speed of the agent-based model in Anylogic fails as the agent abundance exceeds 23. As illustrated, the real agent-based system with serious complicated missions fails even sooner, which proves the functional strength for tackling bulky duties.

The second scenario was defined to measure the overall fatigue of system elements. In this regard, 4 medical aiding rescuer agents and 10 injured ones were defined in the proposed system and SIMIO [2]. Then, two tests were run for the proposed system. Regarding the first test, the agents used the Euclidean shortest path while they used the optimum path algorithm for the second test. SIMIO used its own algorithm to find the optimum path. As displayed in Fig. 14, *b*, the designed optimum path decreases the overall fatigue of system elements. In other words, the proposed solution had the best results, compared to the Euclidean algorithm which reveals the worst.

But the interesting point is the other method used to evaluate this system. The crowdsourcing has different applications, one of the most common app is to evaluate and develop new products. Let's also decide to use a crowdsourcing method to verify our system. Thus, let's provide an interesting information system and shared it with the internal network of the employees of the Central Crisis Management Office of the Markazi province. After displaying several designed scenarios which have been implemented by the volunteers, they were asked to evaluate several parts of the system's processes and record their results in the evaluation system. Fig. 15 shows the user interface of the evaluation system in the internal network environment.



a

b

Fig. 14. About this image: *a* — Effect of increasing the number of agents on system response time in AnyLogic and developed system (vertical and horizontal axis represent the number of agents and time in seconds); *b* — agent fatigue volume (blue line represents the fatigue of agent)

The information collected from about 43 employees of the Crisis Management Office, was reviewed in the evaluation system. The results are displayed in the Table 1. In addition to recorded general comments that reflecting the experts' ideas, a survey was also designed, that is a kind of Crowdvoting. In this survey, the system was measured for feasibility, overall system performance, user comfort, graphical interface suitability, overall cost, comprehensiveness, developmental capability, and effectiveness.

Accordingly, 6 % of the system's experts found it to be inadequate, 7 % rated it poorly, 15 % accepted, 25 % believed that the changes were necessary, and finally 44 % were fully satisfied. Based on this information, the weakest result is in the system's comprehensiveness. Also, due to the frequent costs of crisis management, the system costs are the most consistent. On the other hand, most users have expressed that graphical user interface needs to be essentially changed. However, according to the survey, most users believe in the feasibility of the designed system in practice.

139.141.11.9/Crowdsourcing/disastermanagement

شماره پروپوزال	۱
دامنه طرح	گردش اطلاعات مکانی
ارایه دهنده طرح	هوشنگ عیوضی
جنسیت	مرد
دسته بندی جایگاه سازمانی	استانداری
ارایه دهنده طرح	کارشناس مدیریت بحران
تلفن ثابت	
تلفن همراه	۹۰۱۲۶۷۷۸۶۴
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استان	مرکزی
شهر	اراک

ایده اصلی طرح

این طرح به منظور استفاده از پتانسیل جمع و توده مردم در راستای مدیریت بحران می باشد. بدین منظور از نوعی از سرویس جمع سپرده بهره گرفته شده است. این سرویس ها در قالب یک سرویس اطلاعاتی وظیفه مدیریت و کاهش اثرات سیستم را به عهده دارد

شماره نظر	۱
کاربر	علیرضا حسنی
امکان پذیری	نیاز به توسعه
توانمندی سیستم	نیاز به توسعه
تعامل آسان با سیستم	مناسب
واسط کاربری	نیاز به توسعه
هزینه ها	ضعیف
جامعیت	نرمال
توسعه پذیری	نیاز به توسعه
اثربخشی	مناسب

Fig. 15. Evaluation System GUI in our local web

Table 1

Crowdvoting evaluation system results

Item Case	Inappropriate	Weak	Normal	Need improve	Suitable
Feasibility	2	1	5	4	31
Operation System Level	3	4	8	5	23
User Friendly	1	4	3	16	19
GUI	5	7	4	21	6
Expenses	2	1	17	10	13
Comprehensively	6	8	7	17	5
Extensibility	2	0	3	3	35
Effectiveness	2	2	5	13	21
Total	23	27	52	89	153
Overall score	2.875	3.375	6.5	11.125	19.125
Percentage	6.686046512	7.84883	15.11628	25.87209	44.47674

8. Discussion of experimental results

Experimental scenarios showed that the system can maintain its performance by increasing the number of users and continue to operate without a noticeable drop in performance. These scenarios also show that the designed allocation algorithm can significantly reduce the fatigue of users (rescuers). According to a survey conducted by experts, the system is highly capable in critical situations. According to that survey, good user interfaces, low startup costs, efficiency, extensibility and system effectiveness are the strengths of the system. On the other hand, system integrity and weaknesses in the user interface graphics are some of the things that need to be seriously improved.

On this basis, it can be argued that the algorithm employed in the system performs better than the existing software algorithm in adapting to crisis situations. This is because our algorithm solves the problem by distributing it among intelligent agents. On this basis, it is easier to solve problems in complex situations. On the other hand, it is capable of handling large numbers of users without the loss of power through the use of powerful database structures and tools, as well as a fast and lightweight algorithm.

It also has a very flexible system. With this flexibility, it is able to adapt easily to different crises. But the reason for this high flexibility is the use of various elements in the system architecture, the use of the appropriate conceptual model and the appropriate software design in the user interface and other parts of the system. However, similar systems are highly specialized and are designed for a specific purpose only. This limits the scope of their use.

The system is highly comprehensive. This is because it covers almost all phases of crisis management. The system, with the help of its conceptual model and different users, is able to cover different types of crisis management services. However, similar systems often provide a specific service.

Another issue is the low cost of running this system compared to similar limited systems. This cost, which is about 20 % of other systems, allows managers to easily apply it to different situations. On the other hand, due to the high flexibility of the system, it can be easily applied to other crises after the initial launch of the system. This is due to the type of system design and application of various modules.

On the other hand, micro-management issues have not been formulated in the system. In other words, the executable subroutines in the system are not automated. Also, the system's workflow is not fully compliant with standard instructions. For this reason, given the high customization and flexibility of the system, specialized crisis management workgroups should work on different parts of the system. Also its graphical user interface has no interesting interface. In the condition of the crisis and casualties, a faster interface with high graphics capabilities should be provided. Features such as the ambient intelligence and the smart objects can also be used to design and provide these interfaces.

Altogether, the developed system is a complete framework that can be used to manage various crises. In fact, operation class (Fig. 6, position 7) can cover a variety of crises with the help of the request class (Fig. 6, position 2). It is enough to select the range values of these classes according to the type of crisis.

There are enough tools to develop and customize the various parts. This way it is easily possible to apply different tastes. First of all, the original model was developed in SQL, and any programmer can easily open it and make the desired changes. Second, the mathematical models were functionally created in the database development environment. Therefore, these models can be easily opened and changed (Equations (1) to (6)). Third, standard server-side software modules were used in the server section (ArcGIS Server). These modules are known to experts around the world and they all know how to use and apply changes to them (Fig. 10–12).

Likewise, the use of a simple mathematical computing space in it allows other researchers to conceptually develop the system (Fig. 8). In fact, the use of simple tenor space allows us to easily solve the complexity of the allocation problem.

Nevertheless, despite the positive points, the system, based on comments, and the evaluation has certain weaknesses and there are also topics that should be considered in this regard for further researches:

– the graphical user interface is textual in the current state. Each option also gives a lot of choices to the user. Obviously, in crisis, it is hard to expect the users to choose and submit the desired option with patience and accuracy;

– the lack of access to the wireless network for data transmission in the crisis field. For this purpose, mobile users' operation should be designed intelligently, online and offline. In this way, given the user's state and the prediction of its move, if it is to enter a region without network coverage, it will go ahead with the information it needs to get intelligent from its server and save it to its memory. After the mission in the uncovered area, it will synchronize information automatically once it has entered the area covered;

– using smart systems besides users is another issue that should be considered. For example, how can smart UAV carry out independent or complementary missions on crisis field? In this regard, given the advances in artificial intelligence, the use of artificial intelligence and machine vision, especially in the interpretation and analysis of UAV data in the crisis field is very important;

– about the spatial crowdsourcing service. A complete and comprehensive classification of the services and developing packages and modules in this section to let the researchers focus on development of crowdsourcing service applications instead of building the infrastructure needed to deploy these services.

Likewise system security is something that needs to be addressed. It should be noted that security in crisis management systems is different from other systems. In other words, it can't be expected that the injured will be able to pass the common system's security protocols in an emergency situation. Similarly, rescuers do not have enough time to perform such protocols. Therefore, special security protocols are necessary for the system that is appropriate for the crisis. Of course, a proper security protocol for a crisis environment has other special issues that make it interesting for other researches.

9. Conclusion

1. In this research, a new flexible crowd sourcing service is introduced. Then it is shown how the service, with its basic architecture and structure, can perform different tasks in different phases of the crisis. It is shown that complex crises can be managed, and resolved by combining simple services. Composite system is introduced and it is shown how this system, with the help of its different users and based on crowdsourcing service, covers different phases of crisis management.

2. A system is designed to manage widespread crises or crises that are not usually addressed by governments. Usually in such crises, governments are not capable or interested of managing crises. That's why the power of the people is used to solve them.

– comparison of response time and system performance with a similar system showed that the response time of the system remained almost constant with the increase of the number of agent users to about 100 users, while in the case of some other agent based system software, this time increased linearly. Accordingly, it can be argued that using this solution can produce a robust agent-based system that is commercially usable for big data;

– in another test, the performance of our proposed allocation algorithm is evaluated. In this test, our designed algorithm was compared with two other algorithms. The comparison showed that other selected algorithms depreciated about 70 and 90 percent of the user power after about 3 hours, while our proposed algorithm consumed only 45 percent of the rescue user power. This suggests that using our proposed algorithm can almost double the efficiency of the rescuers in crisis management;

– the performance of the system is also evaluated in eight different areas by the Central Provincial Crisis Management Experts via a crowdvoting system. The results showed that 44 % of the experts evaluated the system as complete. The system also got some great points in terms of extensibility and startup cost. Experts were also very optimistic about the effective and acceptable performance of the system in managing various crises.

3. Multi-user distributing system has specifications that make it suitable to manage different crises:

– the system provides easy and fast operation of mass allocation and guidance;

– the system supports different aspects of the crisis by employing various user groups, including crowds and controls the operations with feedback loops;

– it also supports managers, professional GIS analyzers, team commanders and naive users;

– using spatial crowdsourcing services, in addition to guiding individuals, one can use the various features of this service. For example, the rapid recording of the success or failure of the rescuer assigned to a specific process causes a real-time update of the crisis environment status;

– in implementing this system, a seemingly different spectrum of theoretical foundations played a well-formed role in a coherent solution. In other words, a math framework in the form of multi-agent environments, combined with the concept of time-geography in a database environment and a few different software environments, are well established and work well;

– the system is operationally improving the indicators of operations control, such as the amount of rescuers' fatigue or the delay time of missions;

– the cost system setup is really low;

– the structure of the system allows us to easily develop it in different parts. For example, a complete process of automatic assistance with an Unmanned Aerial Vehicle can be added to the system, coordinated with the operation of different parts of the system;

– the system allows for various spatial analyzes based on information collected directly or indirectly. In other words, a GIS analyzer can check the data continuously to implement new applications of the system.

4. The graphical user interface of mobile users was easily tailored to our needs. Due to its flexible structure and architecture, this interface can be set up for any type of crisis with just a few simple settings in DBMS. On the other hand, it is easily connected to various components of the system. It also allows to extract a variety of spatial, descriptive or other ancillary information. This interface supports various missions with the help of a flexible information protocol. This feature is also one of the highlights of this interface.

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