Volume 1, 2019 International Journal of Electrical Engineering and Computer Science (EEACS)

Received: August 9, 2018. Revised: February 12, 2019. Accepted: March 10, 2019. Published: March 16, 2019.

HaReS: Real-time hazard reporting and loss estimation system

Yasar Guneri Sahin
Department of Software Engineering
Izmir University of Economics
Izmir, Turkey
yasar@ieu.edu.tr

Diaa E. FAWZY
Department of Electrical and Electronic Engineering
Izmir University of Economics
Izmir, Turkey
diaa.gadelmavla@ieu.edu.tr

***Abstract*— The main aim of this paper is to present a first high level design of a local real-time Hazard Reporting System (HaReS). The system assists in accelerating the processes of human relief in case of natural or man-made disasters. In addition, the system assists the National Disaster Management Centers (NDMC) to estimate economic loss caused by natural or man-made hazards, and to manage the consequences of disasters within the shortest possible period; thus the system intends maximum recovery in minimum time. The system is divided into two main subsystems. The first subsystem – Real-Rime Monitoring Environment (RTME) - gathers data about disaster by monitoring the environment, such as buildings' health and possible numbers of buried under debris, using several sensors. The second subsystem, Loss Estimation (LE), provides, classifies and analyzes crucial data which can be used to estimate disaster losses and their potential direct and indirect consequences.**

Keywords*— *Monitoring environment; Building health; Disaster management; Real-time systems

I. INTRODUCTION (*Heading 1*)

The processes of civil structural health monitoring, information collection and economic loss estimations in case of small scale or large-scale natural disasters (e.g., earthquakes) are highly complex and time-consuming tasks. Although traditional monitoring systems are being transformed into less complex and costly wireless embedded systems, a self-consistent and real-time system is still not currently available. Decision-making on rapid response to casualties and loss estimation procedures in case of a disaster is enormously affected by the time lag needed for information collection, and the uncertainties in the collected data. Moreover, several other factors, such as limited information and the unreliable nature of the manually collected data, may result higher error bounds in estimating losses.

Software tools based on deterministic and probabilistic models (e.g. HAZUS, MAEviz and QUAKELOSS2) are merely predictions based on the currently available scientific and engineering knowledge, rather than precise forecasts [1-4]. For example, these tools can predict the impact of the hypothetical earthquake, and estimate the level of physical damage, direct and indirect socio-economic losses, which can be useful for predicting potential losses, future mitigation and recovery planning. However, these methods do not reflect an accurate overview of the disaster, and are not suitable for immediate human relief plans. In addition, currently there exists no standardized estimation technique or framework for compiling loss estimates from individual disasters. Most estimates are ad-hoc, consisting of only those losses that were significant in a particular event. These differences provide an excellent opportunity for assessing the value, needs for real-time systems. Real-time monitoring systems avoid the uncertainties in model parameters (e.g., determining the actual disaster magnitude and ranges, source location, occurrence rate and different soil reactions), thus, the proposed system results in greater accuracy in loss estimation and a better informed decision making process.

The urgent need for a real-time data collection which allows the prompt reporting to the NDMC of the time stamp, geographical location, number of occupants inside buildings, and accurate description of the partial or total structural damages. Interfaces to this system can then be developed to support reporting the number of missing people inside buildings at the time of disasters for rapid relief (not only for earthquakes, but also in case of fires and floods), so that decision makers can more easily determine whether buildings are safe for re-occupancy, and estimates can be computed for direct and indirect economic losses.

Six steps are required for consistent process in human relief efforts and loss estimation following disasters: (1) the collection of real-time information about numbers of people inside buildings, (2) the collection of real-time information about the actual status of buildings, (3) inventory data for buildings and infrastructures, (4) a geographical Information System (GIS), (5) information about soil conditions, age and response of structures and any uncertainties in these measurements, and finally, (6) modeling and calculation algorithms. Therefore, to achieve the aforementioned goals, we envision a self consistent and real-time system, focused on human, buildings and structures, with five major components as stated in National Academy Press [5]:

- A regional database of collected real-time data
- The capacity for event-to-loss mapping
- An algorithm for emergent response to infrastructure repair

- An algorithm for private commercial/industrial repair
- An algorithm for residential reconstruction

In the present study, we focus on the first and second goals, namely the collection of accurate information about number of people inside buildings, the actual status of buildings and whether they are safe for re-occupancy. The remaining goals will be addressed in future work.

II. RELATED WORKS AND MOTIVATION

Rapid changes in sensing, wireless technologies and computer-vision based systems enable the appraisal the benefits of these technologies in the civil and environmental engineering [6, 7]. The safety and serviceability of a structure can also be assessed by monitoring both the extent of deformation and the maximum values of displacements, using digital cameras and employing imaging and Photogrammetry techniques. Olaszek used digital charged coupled device (CCD) cameras to measure displacements of a particular location on a highway bridge [8]. The main shortcoming of such image-based structural monitoring techniques is the light requirement, making measurement at night difficult.

Because of their success in estimating the variation of displacements over time, acceleration wireless sensors have been extensively used to accurately measure the vibration levels at given points of a structure [9, 10]. Recently, a number of researchers have used the global position system (GPS) to measure the static and dynamic displacement of a structure [9, 11]. However, the GPS has many limitations, including the inability to measure displacement in the interiors of the buildings or through obstacles, in addition to its limited precision level [12]. In health monitoring of structures, deflection accuracy in the order of millimeters is required.

A new laser scanning technology has been recently developed that allows accurate three-dimensional (3D) location information for a structure or an entire building to be obtained without being restricted to a particular location on the structure, and the process is not affected significantly by the environmental conditions [13].

National Disaster Management Centers are in urgent need of accurate information for rapid and critical decisions on which lives and property depend. This can only be achieved by a real-time system. One significant advantage of our proposal is the combination of different techniques to increase the system reliability and availability, thus increases the accuracy of the collected information. Therefore, to ensure correct decisions are taken, actual and more accurate views of the disaster areas are taken into account.

Using the currently available technologies and computational power, the proposed system is designed to provide the following functions:

- The presentation of an immediate picture of structural damage of buildings and the number of people inside at the moment of disaster.
- The assessment and evaluation of losses (direct and indirect costs for reconstruction of collapsed buildings, and reallocation people).
- The calculation of the approximate time need for restoration/reconstruction for buildings.
- Classification algorithms for assembling information about buildings, infrastructure utility and economic data.
- Databases combined with geographical information system (GIS) for information storage and the convenient manipulation and visualization of loss estimation data.
- Support for decision makers based on the case-based-reasoning (CBR) technique.

III. PROPOSED SYSTEM DESIGN

The HaReS (Real-Time Hazard Reporting System) is designed to assist the National Disaster Management Centers (NDMC) in increasing their capacity for dealing with casualties immediately after the event, and in estimating the direct and indirect economic losses by providing accurate environmental data. The proposed system is a combination of two main subsystems and a data base module as shown Figure 1.

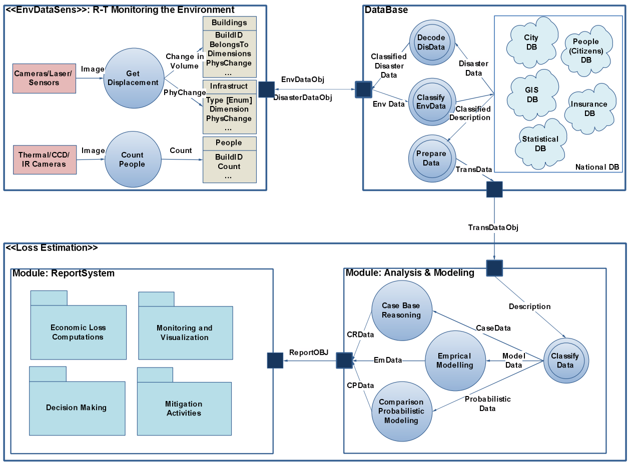


Fig. 1. HaReS architecture and data flow schema

1. The <<EnvDataSens>> is the subsystem that monitors the environment (including people, structural dimensions, roads) and continuously (in real-time) collects data about the status of the buildings, and the number of people inside. The gathered information is then sent to the database module for future use by the NDMC.

2. The <<Loss Estimation>> subsystem is an integration of two modules: “Analysis & modeling” and the “Reporting System”. This subsystem is used to estimate and report the possible consequences of disasters, including economic loss, damage to buildings, direct and indirect effects on the population, and debris issues.

3. The <<Database>> is a module which stores all data about the disaster and the environment, it includes all pre-disaster images of the buildings, the geographical locations of

the structures, road maps, previous disaster data, and the available evacuation plans. This module is shared by the two subsystems mentioned in points 1 and 3 and is usually located at the NDMC.

The workflow and dataflow of HaReS (as shown in Figure 1) start with the collection of time sequences of information about people and structures; namely the numbers inside structures, and the changes in structure, carried out by the Environmental Data Object module provided by the EnvDataSens subsystem. The data are then sent for storage in the database, which decodes the objects coming from the EnvDataSens and directs the contents to the related tables.

In case of a disaster, the Loss Estimation subsystem creates a request to load the gathered data from the database module. The Analysis & Modeling module is then activated to classify and group the collected data for the analysis and reporting stages. In the current system, we suggest using the Case Base Reasoning (CBR) technique for building accumulative scenarios which help the decision makers, more details about the CBR are given in section 3.

For the computation of the direct and indirect economic losses, we use the well known equations given by FEMA [2]. The main advantage of this current study is the more accurate data collection methods, resulting in more realistic data. More details about this part are given in section 3. In the final stage, the report object is created and then sent to the Report System module to report the various losses and consequences of the disaster. The following subsections describe the higher level details of the system.

A. *Real Time Monitoring the Environment*

Figure 2 shows infrastructure of real time monitoring environment system (RT-ME) used in the HARES and its high level architecture. The system is composed of three main components: distributed detectors (e.g., thermal or CCD cameras, displacement sensors and LASERs), the communication medium for data communication (e.g., PTSN, 3G and Satellite links), and the management software at the NDMC.

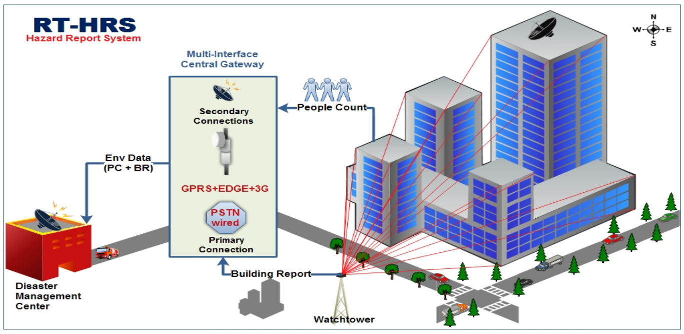


Fig. 2. RT-ME infrastructure [14]

In the current system we employ different transmission media, routes, and standby sensors in order to guarantee maximum availability and reliability.

Special attention is given to monitoring high buildings, hospitals, shopping centers and critical buildings, where there is a high probability of finding a greater numbers of people. The EnvDataSens subsystem is continuously tracking the numbers inside buildings, changes in the dimensions of buildings, and also identifies buildings which have been damaged or have collapsed.

The main sensors (thermal cameras placed at the exit points of the buildings) record the number of people inside the target buildings, and send this information instantly to the NDMC. This process occurs simultaneously with the monitoring of changes in building structure by other sensors.

The system records any changes in shape or displacement by measuring change in volume, and informs the NDMC. The software at the NDMC checks the displacement severity (an optional parameter –LoC: Level of Change- is used to determine the severity of change or displacement, e.g. 10% or greater displacement or change in volume can be accepted as serious damage), and it sets the building status as damaged or undamaged, according to severity results. If a building's status is "damaged", then the people inside should be considered as casualties, therefore the HaReS automatically changes the status to damaged or collapsed, and those inside to casualties under debris.

If more than one building is damaged simultaneously (as in the case of a natural disaster, such as an earthquake), the system prioritizes the buildings according to the severity of damage and the number of the casualties under debris. The highest priority is given to the more densely occupied and more seriously damaged buildings. In addition to the damage to buildings, and the people count, the system also supplies data about locations and the shortest routes.

The following section gives details of the types of sensors which could be used for detection of damaged buildings and the common high level framework.

1) *Detecting collapsed buildings:*

The RT-ME proposes the use of CCD (IP) cameras, lasers or displacement sensors or combination of these to detect damaged or collapsed buildings. The selection of appropriate detector/s depends on several parameters, such as size of the building, condition and importance of the building and cost restrictions. The following subsections give details of the sensors and their usage.

IP-Cameras: An IP-camera located on the top of a watchtower (or pole) continuously scans one or more buildings (depending on the size of the scanning area) and captures the building images at a certain frame rate. Here, frame rate (fps) denotes the number of images captured by a camera per second. The frames (images) are firstly filtered and converted to Monochrome or X-ray images, and then periodically stored in a historical image array (first in first out queue). Following this, the array items (images) are compared with the original image with respect to a change in volume until the difference in volume becomes constant. The following algorithm shows the comparison process.

Here ConfidenceLevelEpsilon in the algorithm is used to stop the detection process, which means that the change period is completed and building is stable.

```
i:=0;
Delta := 1;
VolumeChange := CalculateTheVolumeChange(framearray[i],org_frame);
While (Delta <> ConfidenceLevelEpsilon) do
Begin
    i:=i+1;
    if (i>MaxItemsSize) then i:=0;
    PrevVolumeChange := VolumeChange;
    VolumeChange := CalculateTheVolumeChange(framearray[i], org_frame);
    Delta := VolumeChange - PrevVolumeChange;
End;
```

The comparison results are used to detect any change in the form of buildings. If any change in the volume occurs, the most recent position of that building (framearray[i]) is retrieved from the historical image data and sent to NDMC, where the software computes the approximate amount of change in volume. If the change is greater than LoC (usually 10%), the system sets the building status to “damaged building”, and those inside are considered as casualties in need of rescue. Figure 3 shows an example scenario for a building collapse and detection of the collapsing using comparison.

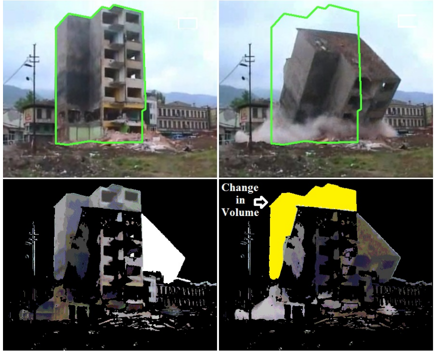


Fig. 3. Sample detection of a collapsed building using an IP-Camera

In this detection method, the value of the frame rate is critical. On the one hand, the time interval between two captures must be sufficient for the detection process to be completed. On the other, excessive delays in the capture of images in the detection process can lead to a reduced number of images and therefore a decrease in reliability. Thus the frame rate should be set to a maximum of 2 images per second.

In the meanwhile, to increase the total accuracy and reliability of the system, there are a number of complimentary or verification mechanisms, such as the use of witnesses including taxi drivers and apartment directors. In case of collapse, these people are in a position to provide the NDMC with immediate post-disaster information on building conditions, which can be used to verify data supplied by the proposed system, or to add information about other collapsed buildings not detected by the proposed system. Furthermore, Mobile Electronic System Integration, “MOBESE”, for network traffic monitoring system can also be used as an alternative to watchtowers.

Laser: This method is expensive and difficult to implement, due to the relatively high cost of Laser scanners, their very limited scanning capacities (0-250m), and the potential disturbance caused by the beam. However, the reliability level of the Lasers is very high compared to other methods.

In this method, a Laser scanner located on a pole periodically scans a previously define reference point on a building. During this operation, the data gathered from these points is used to sketch a two dimensional graphic on a plane, which reveals the shape of the building. These processes are performed for each scanning period, and the most recent outline is compared with the original. The system automatically calculates any change in volume using reference points. A sample scenario is shown Figure 4. After the calculation, the NDMC is informed through various communication mediums. To achieve the detection of the damaged buildings, different detection algorithms can be used for laser imaging, increasing the reliability of the system [15-17].

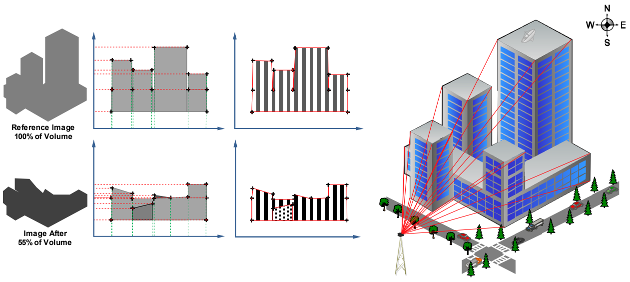


Fig. 4. Sample detection of a collapsed building using Laser scanner

Here, the scanning frequency is crucial in Laser usage. The time between two Laser scans should be maximized (e.g. 20 or less scans per hour) to avoid unnecessary disturbance.

Displacement Sensors: Building displacement sensors in several critical locations continuously record the distance between each other, and perform displacement checking with respect to reference points [14]. The system is illustrated in Figure 5. If any change in distance or displacement is detected, the system calculates the amount of displacement and sends the results to the NDMC, where software compares the amount of displacement with the LoC parameter. A decision is then made as to whether the building is considered damaged or not; if set to damaged, then the people inside are set to “casualties”.

In the experiments and simulations, a number of problems have been observed in the use of IP-cameras for building monitoring, as follows:

- Weather conditions may affect accuracy.
- Vibrations may lead to difficulties in capturing images, watchtower cameras may, therefore, provide blurred images. This makes the comparison more difficult, therefore inaccurate comparisons may result.
- Watchtowers may collapse with buildings.
- Installation costs may be excessive for regions with large numbers of buildings.

Some of these problems can be resolved using different techniques and algorithms, and these should be taken into account in selection of detection method (collapsed buildings).

In addition to all methods previously mentioned should be compared in terms of their advantages and disadvantages. These methods include Synthetic Aperture Radar (SAR) and satellite imaging based detection [18-20].

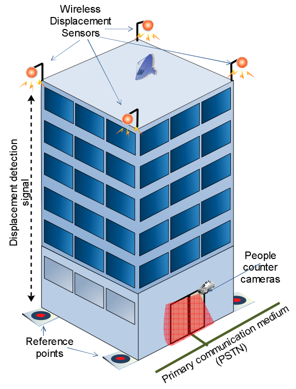


Fig. 5. Building monitoring using wireless displacement sensors [14]

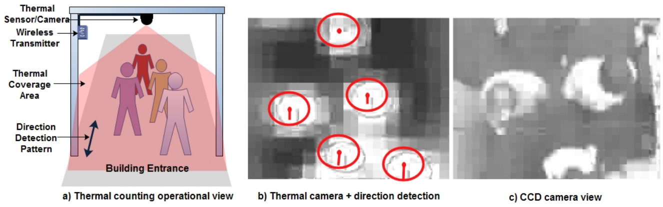
Table 1, which gives the approximate availabilities of the methods, can be used as a scale for the detection of the most appropriate method.

1) People counting:

A people-counting system is essential to identify the numbers inside the debris at the time of collapse, so that in the event of an evacuation resulting from a natural or man-made disaster, it can be confirmed whether all have been evacuated. This can only be automated with the use of extremely accurate human detection sensors which record the number of people passing through entrances and their movement directions. The problem of people-counting has been revisited for a variety of different purposes, for example for security and energy saving systems [21]. It is important that the proposed system should achieve two main functions: the collection and storage of the entry pulses from the counting sensors, and the data analysis, which involves the calculation of the amount of people inside a building, in the process of entering, and the immediate vicinity.

TABLE I. THE BUILDING DETECTION METHODS COMPARISON

Method	**Coverage**	**Availability**	**Reliability**	**Accuracy**	**Installation Difficulty**	**Usability**	**Maintenance**	**Cost**
IP-Cameras	Medium (0-1 km^2)	Easy	Mid	Mid	Easy	Very High	Easy	Very low
Lasers	Small (0-0.09 km^2)	Easy	Mid-High	Mid	Mid	Medium	Easy	Low
Displacement Sensors	Small (0-2000m^2)	Medium	Mid-High	Mid	Difficult	Difficult	Low	Low
SAR Imaging	Huge (0-10000km^2)	Difficult	High	High	N/A	Difficult	N/A	High
Satellite Imaging	Huge (0-10000km^2)	Difficult	Mid-High	High	N/A	Difficult	N/A	Mid



a) Thermal counting operational view b) Thermal camera + direction detection c) CCD camera view

Fig. 6. People counting schema using thermal detectors

In recent years, different kinds of technologies have been used for constructing non-contact and non-obstructing automatic counters, such as infrared beams, CCD cameras, thermal imaging and pressure-sensitive mats [22]. To extract this information, some technologies, such as CCD cameras, require time-consuming and complex image processing algorithms. Thermal detectors are very suitable for people detecting using body temperature, and can be very accurate if placed sufficiently close to the entrance doors, as shown in Figure 6 [23]. Furthermore, since thermal transceivers detect the heat emitted, they are able to function all lighting levels (even in complete darkness) in real time, without the need for the complex background removal algorithms used in computer vision systems. This results in a more stable and accurate people count. However, without multi-sensing support, in certain conditions, such as high temperatures, these may provide inaccurate results, thus need to be supported (verified) by other techniques, such as infrared detectors.

One solution to the problem of accurate people counting is to use an array of infrared detectors, a system which has demonstrated detection accuracies of more than 95% [24]. In this technique, the detection process, based on measuring the difference between the total emitted flux and the mean output of the floor, allows the movement direction to be detected from the slopes of the detected areas in the thermal images. The processing and information extraction is done in real time by means of a built-in signal processing circuit.

The RT-ME system proposes use of a combination of thermal camera and infrared sensor array techniques for large scale buildings, such as hospitals, shopping and entertainment centers, and thermal cameras alone for smaller buildings, to reduce cost. Factors such as cost, building status and level of disaster' risk will determine whether this method or alternatives will be chosen.

B. Economic loss estimations and decision support

In this section we briefly present the basic components of the suggested loss estimation and decision support system. The main consequences of natural disasters are losses caused by direct and indirect physical damage. Indirect losses are obviously more difficult to measure than those stemming directly from physical damage. In both cases, costs of replacement and repair should be evaluated. The accurate computation of loss estimations using accurate data is essential in preparing future disaster plans and facilitating good decision-making at different levels [5].

This paper presents an analysis based on real-time information collection immediately following a natural disaster. The framework shown in Figure 7 serves as the basis for the present study [25]. The objective is to demonstrate how the proposed method can assist in the analysis and comparison of the possible consequences of the direct and indirect physical damage and losses on society. The main aim is to develop an intelligent system which is able to make use of comprehensive databases of economic, social, and demographic information in the estimation of the losses caused by disasters.

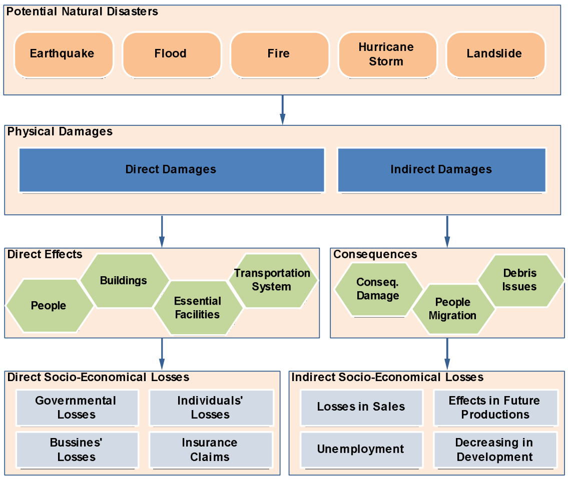


Fig. 7. A framework for hazards analysis and loss estimation effects

1) Computation of the initial losses:

The process of calculating the actual consequences of physical and economic losses in catastrophic events using real-time data will be discussed in greater detail in a separate work. The aim of the current study is to provide a basic treatment of the problem.

In recent years there have been great improvements in the computations of initial losses in the wake of the disasters and their immediate consequences, especially with the development of geographical information systems. However, it is important to note that most of the developed tools are still based on either manually collected data or on probabilistic models which may not be an accurate reflection of the event itself.

Our current focus is to increase both the accuracy of the collected data and the processing speed. It is also important to mention here that another of our aims is to integrate all previous hazard information in an accumulative intelligent algorithm for comparisons and future plan preparations. The achievement of these two aims has the potential to facilitate faster and more accurate decision.

Losses are usually classified into two main categories; direct losses (i.e., human losses, destruction of buildings or infrastructure), and indirect losses, which are the result of interrupting regular economic activities of the affected region. In the current study, we employ the well-known equations developed by FEMA [2], together with the use of our own real-time data to calculate the initial losses after an earthquake. It is important to note that these computations should be repeated frequently as a function of time through a series of improved data, thus the procedure will result in a more accurate view.

According to FEMA, the basic formula used for the computation of economic losses for structural rebuild or repair due to partial or complete damage is given by (Parameters details can be seen in FEMA)

$$Loss = CI \cdot \sum_{i=1}^{oct}\sum_{j=1}^{mbt}\sum_{k=1}^{ds} A_{i,j} \cdot P_{j,k} \cdot C_{i,j,k} \quad (1)$$

For the current study, we slightly modify equation 1 to be valid for the use of real-time data. The probability function, $P_{j,k}$ is to be replaced by the actual status of buildings collected after the event. The other parameters, CI, $A_{i,j}$ and $C_{i,j,k}$ are pre-compiled data contained in the NDMC database. Regularly, updated data about building is a essential in providing an accurate overview of the event.

As the computations should be done in nearly real-time, we suggest dividing the affected regions into smaller parts with the help of a geographical information system. The computations should be repeated frequently on the regional servers of the NDMC.

The number of casualties $K_{s,i}$ of severity level i (i.e. injured people and fatalities) caused by either total or partial collapse of buildings can be evaluated using the following equation [2];

$$K_{s,i} = \sum_{j=1}^{mbt}\sum_{k=1}^{ds} CR_{j,k} \cdot P^{*}_{j,k} \cdot pop._{j} \quad (2)$$

The input parameters of equation 2 are to be collected from different sources, the $pop._j$ is directly delivered by the people counting sensor placed inside buildings shortly before the event occurrence. For the injury severity i, additional interfaces to hospitals may be required. The damage probability function $P^{*}_{j,k}$ will be replaced by the actual data, as in equation 1.

2) Disaster management and decision making support system:

These systems allows past scenarios to be retrieved for the purpose of providing support for problem solving, and enabling learning from previous experience.

In this section we briefly describe an approach for developing an intelligent knowledge-based disaster decision support system, based on the case-based reasoning technique (CBR). Full details of the procedure will be given in a separate study by Sahin and Fawzy (research in progress). The CBR system is an approach for solving problems based on solutions of similar past cases (1 and 2). In technical domains, CBR are widely used in decision support and for diagnostic problems.

A CBR system will contain a number of previous cases and the actions taken to resolve them. When a new case is described, a related and similar case is retrieved along with its resolution. Since the resolution may not be directly applicable, the related case is used for initial guidance only, and is adjusted as necessary. The new case, with its revised solution, is then retained for future usage. The four main processes involved in this system, referred to as the CBR-cycle, are as follows: 1-Retrieve the case that most resembles the current one, 2-Reapply this information to solve the problem, 3-Revise the suggested solution, and 4-Retain the revised solution for future usage [26]

The main feature of the current approach distinguishing it from other disaster and loss estimation systems is its implementation in a time history scheme, which takes into account past events in order to provide improved current decisions.

IV. SIMULATION RESULTS AND DISCUSSIONS

Since the possibilities for testing the proposed RT-ME system in real environment are limited depending on the actual occurrence of earthquakes and other disasters. Several attempts are conducted to assess its usability and reliability of the system. We first divide the system simulation into two parts, the first part deals with the counting of the number of persons inside buildings during the disaster time, and the second part concerns with damage detection of structures.

The real-time monitoring of buildings for damage detection was first simulated by Sahin et.al [27], and in the current work, we restructure this simulation with the statistically found parameters that mostly affect the damage level of buildings during earthquakes. Figure 8 shows snapshots of the simulation software that is specially written for this study, and its user interface.

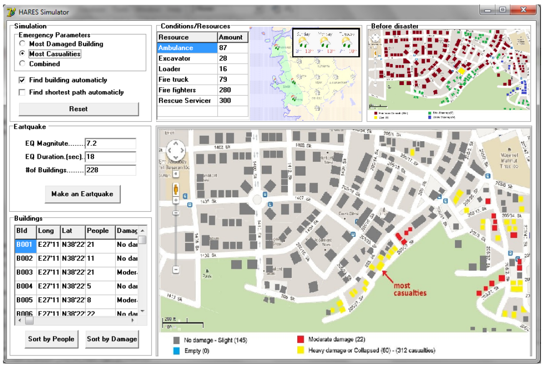
Data collected by Sengezer, Ansal & Bilen for three big earthquakes in Turkey showed that the parameters that mostly affect the structural resistance to earthquakes are: 1) building type (e.g., wood, reinforced concrete, steel), 2) site conditions (e.g., hard, soft), 3) number of stories, 4) building position (e.g., block, separated), 5) ground floor use (e.g., residential, public, commercial) [28]. The dependence of the damage function of a structure on these parameters is expected to be non-linear, and attempts to extract the damage function are in progress and will be presented in a separate work.

In the current simulation, we take these parameters into account and for simplicity purposes we assume linear dependence of damage function on these parameters and we scale down the number of buildings by a factor of 1/12.

In simulation, several assumptions were made as follows:

- Maps and satellite images were gathered from Google Earth [29]
- The total number of buildings used in simulation was 228
- Daytime was chosen for simulation time

The expected result of the simulation software was identification of the building with most damage (especially heavily damaged or collapsed), and the building with most casualties, or the building that was both of these, i.e. the building in most urgent need of rescue. Furthermore, the simulation program showed also the potentially shortest route to the building with the greatest amount of damage.



Emergency Parameters
○ Most Damaged Building
● Most Casualties
○ Combined

☑ Find building automaticly
☐ Find shortest path automaticly

Conditions/Resources

Resource	Amount
Ambulance	87
Excavator	28
Loader	16
Fire truck	79
Fire fighters	280
Rescue Servicer	300

Eartquake

EQ Magnitute........ 7.2
EQ Duration.(sec).. 18
#of Buildings........ 228

Buildings

Bld	Long	Lat	People	Damag
B001	E27'11	N38'22'	21	No dai
B002	E27'11	N38'22'	11	No dai
B003	E27'11	N38'22'	21	Moder.
B004	E27'11	N38'22'	5	No dai
B005	E27'11	N38'22'	8	Moder.
B006	E27'11	N38'22'	22	No dai

■ No damage - Slight (145)
■ Empty (0)
🟥 Moderate damage (22)
🟨 Heavy damage or Collapsed (60) - (312 casualties)

Fig. 8. A HARES simulator screenshot for RT-ME

The simulation program has been executed about 50 times with different earthquake parameters (building locations were shuffled, number of people inside the buildings were changed and earthquake magnitude for each try), and the results were recorded. After each execution, the results showed that the RT-ME software worked efficiently and the simulation provided the expected results and data. For instance, 60 of 228 (26%) of the buildings would collapse and 312 casualties would wait to be rescued if the earthquake happens with the magnitude of 7.4. The exact number of the casualties under debris, the buildings with most casualties and the shortest paths to reach these have been sufficiently provided by the software. In addition, the simulation demonstrated that the system would be very effective in determining the buildings with the greatest need for an urgent response in terms of saving lives.

Since the real data were used in the simulation and no function was used to create earthquake scenarios, we did not need to compare the results to other studies. Our expectation was only to see that the software works properly in case of earthquake. In addition, this paper presents a high level design of our proposal, we, therefore, tried to open a new frontier to the researchers who want to work in this concept.

V. CONCLUSIONS

There is nothing more valuable than a human life. Furthermore, in case of a disaster, the most significant goal is to maximize the number of rescued people in the minimum amount of time. Thus, the proposed system aims at directing rescue teams to the buildings suffering from the most damage, where help is likely to be most effective in terms of saving lives.

Moreover, the HaReS is designed to create a combined solution for real-time reporting and loss computation for natural or man-made hazards, and can provide decision makers and relief agencies with much more realistic views of events. The current work focuses on real-time environment data gathered about building conditions and people counting. Since the system aims to help NDMCs assist a greater number of casualties in the case of a disaster, such as earthquakes, wildfires, man-made fires and floods, it is a critical system requiring high levels of reliability and accessibility. By constantly continuously monitoring the environment, this system is able to detect changes, for example building dimension, with a high degree of accuracy.

Experiments and simulations showed that the system with IP cameras for monitoring the environment and thermal cameras for people counting has a great potential for providing reasonably reliable, rather than completely accurate results. While HaReS with IP and thermal cameras have several advantages, such as ease of maintenance and installation, it has an important constraint in that each camera can be used only for a few buildings because of their limited capacity. To create a truly global solution, detection methods such as IP-Cameras with SAR and satellite monitoring should be integrated into systems that are considerably more sophisticated.

If the proposed system were to include more than one detection method (e.g. IP-Cameras with Lasers or IP-Cameras with displacement sensors), this would enable more reliable and accurate data to be gathered from the environment. In addition, HaReS with combined detection methods may also reduce the negative effects of environmental conditions, such as adverse weather conditions (e.g. fog and heavy rain) and storms.

ACKNOWLEDGMENT

The authors would like to thank Ahmet Oktay Kabar, Bengi Saglam, Erkam Tek and the staff of Izmir Governorate for their valuable contributions.

REFERENCES

[1] Kaestli, P., Wyss, M., Bonjour, C., Wiemer, S. & Wyss, B.M. (2007). A new Tool for Estimating Losses due to Earthquakes: QUAKELOSS2. American Geophysical Union, Fall Meeting 2007; Abstract #S51A-0222. Retrieved from: http://adsabs.harvard.edu//abs/2007AGUFM.S51A0222K. Available on Jan 14, 2011.

[2] FEMA: Federal Emergency Management Agency. (1997). HAZUS. National Institute of Building Services Documents 5200 to 5203, Federal Emergency Management Agency, USA.

[3] Seligson, H.A. (2011) HAZUS Enhancements and Implementation for the ShakeOut Scenario Earthquake. Retrieved from: http://www.colorado.edu/hazards/shakeout/hazus.pdf, Available on Jan 14, 2011.

[4] Navarro, C., Lee, J.S., Tolbert, N., Hampton, S., McLaren, T. & Myers, J. (2008). MAEviz: Seismic Risk Assessment Environment - bridging the gap between research and practice. Poster presented at AGU 2008 Fall Meeting. San Francisco, CA. December 15-19, 2008.

[5] National Academy Press. (1999). The Impacts of Natural Disasters: A Framework For Loss Estimation. Washington, D.C. 1999. Retrieved from: http://www.nap.edu/openbook.php?record_id=6425&page=R1, Available on Jan 14, 2011.

[6] Lu, K.C., Wang, Y., Lynch, J.P., Loh, C.H., Chen, Y.J., Lin, P.Y. & Lee, Z.K. (2006). Ambient vibration study of the Gi-Lu cable-stay bridge: Application of wireless sensing units. Proceedings of the Society of Photo-Optical Instrumentation Engineers (SPIE); Volume: 6174 Pages: D1741-D1741.

[7] Lynch, P.J., Law, H., Straser, E.G., Kiremidjian, A.S. & Kenny, T.W. (2000). The Development of a Wireless Modular Health Monitoring System for Civil Structures, In Proceedings of the MCEER, Las Vegas, NV, USA, November 30-31, 2000.

[8] Olaszek, P. (1999). Investigation of the dynamic characteristic of bridge structures using a computer vision method. Measurement, 25, 227-236.

[9] Tamura, Y., Matsui, M., Pagnini, L.C., Ishibashi, R. & Yoshida, A. (2002). Measurement of wind-induced response of buildings using RTK-GPS. Journal of Wind Engineering and Industrial Aerodynamics 2002, 90, 1783-93.

[10] Suzuki, M., Saruwatari, S., Kurata, N. & Morikawa, H. (2007). A high-density earthquake monitoring system using wireless sensor networks Proceedings of the 5th international conference on embedded networked sensor systems, 373 – 374.

[11] Loves, J.W., Teskey, W.F., Lachapelle, G. & Cannon, M.E. (1995) Dynamic deformation monitoring of tall structure using GPS technology. J. Survey. Eng., 121, 35-40.

[12] Breuer, P., Chmielewski, T., Gorski, P. & Konopka, E. (2002). Application of GPS technology to measurement of displacements of high-rise structures due to weak winds. J. Wind Eng. Ind. Aerodyn, 90, 223-230.

[13] Park, Y., Jeong, S., Suh, I.H. & Choi, B.U. (2007). Map-Building and Localization by Three-Dimensional Local Features for Ubiquitous Service Robot. Lecture notes in computer science, 4412, 69-79.

[14] Fawzy, D.E. & Sahin, Y.G. (2010) .RT-HRLE: A System Design for Real-Time Hazards Reporting and Loss Estimation Using Wireless Sensors, IEEE International Conference on Education and Management Technology (ICEMT 2010), Cairo, Egypt. November 2-4, 205-209.

[15] Frueh, C., Jain, S. & Zakhor, A. (2005). Data Processing Algorithms for Generating Textured 3D Building Facade Meshes from Laser Scans and Camera Images. International Journal of Computer Vision, 61(2), 159–184.

[16] Pu, S. & Vosselman, G. (2009). Building Facade Reconstruction by Fusing Terrestrial Laser Points and Images. Sensors, 9, 4525-4542.

[17] Jaakkola, A., Hyyppä, J., Hyyppä, H. & Kukko, A. (2008). Retrieval Algorithms for Road Surface Modelling Using Laser-Based Mobile Mapping. Sensors, 8, 5238-5249.

[18] Aoki, H., Matsuoka, M. & Yamazaki, F. (1998). Characteristics of Satellite SAR Images in the Damaged Areas Due to the Hyogoken-Nanbu Earthquake. The 19th Asian Conference on Remote Sensing November 16-20.

[19] Trianni, G., Dell'Acqua, F., Gamba, P. & Lisini, G. (2008). Fusion of GIS and SAR Statistical Features for Earthquake Damage Mapping at the Block Scale. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B4. Beijing, 1665-1670.

[20] Brunner, D., Lemoine, G. & Bruzzone, L. (2010). Earthquake Damage Assessment of Buildings Using VHR Optical and SAR Imagery. IEEE Transactions on Geoscience and Remote Sensing, 48(5), 2403-2420.

[21] Yoshiikea, N., Aritab, K., Morinakaa, K., Hashimotoa, K., Kawaguria, M. & Nishinoa, A. (1995). Human information sensor. Sensors and Actuators A: Physical, 48(1). 73-78.

[22] Huang, X., Li, L. & Sim, T. (2004). Stereo-based human head detection from crowd scenes. Image Processing, 2004. ICIP'04. 2004 International Conference (ICIP), 2, 1353-1356

[23] Traf-Sys, People Counting Systems. Retrieved from: http://www.trafsys.com/people-0counters.aspx, Available on Jan 05,2011.

[24] Hashimoto, K., Kawaguchi, C., Matsueda, S., Morinaka, K. & Yoshiike, N. (1998). People-counting system using multisensing application. Sensors and Actuators A Physical, 66, 50-55.

[25] Yeh, C.H., Loh, C.H. & Tsai, K.C. (2007). Overview of Taiwan Earthquake Loss Estimation System. Natural Hazards, 37, 23-3.

[26] Aamodt, A. & Plaza, P. (1994). Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches. Artificial Intelligence Communications, 7(1), 39-59.

[27] Sahin, Y.G., Kabar, A.O., Saglam, B., Tek, E. (2011). Real-Time Monitoring Environment to Detect Damaged Buildings in case of Earthquakes. International Conference on Digital Information Processing and Communications, Series of Springer LNCS, Jul 7-9, 2011, Ostrava, Czech Republic, Digital Information Processing and Communications, vol:188, pp:419-425.

[28] Sengezer, B., Ansal, A. & Bilen, O. (2008). Evaluation of parameters affecting earthquake damage by decision tree techniques. Natural Hazards, 47, 547-68.

[29] Google Maps, Google, Retrieved from: http://maps.google.com, Available on Jun 15, 2012.