Developing information systems and their HCIs for major disasters

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Abstract: Eastern Marmara region of Turkey was hit by two major earthquakes on 17 August and 12 November 1999. These disasters claimed in excess of 20,000 lives and an important of the infrastructure was destroyed along with dwellings and public buildings. The epicenters of the earthquakes were 100 and 200 km away from Istanbul, the most populous city of Turkey. Although there was not major loss in Istanbul in the 1999 earthquakes, the city is even closer to the epicenter of the next potential earthquake in the same fault line.

In the context of disaster preparedness of large proportions, it is important to develop information systems for the use of authorities and general public. Those systems and their interfaces with humans must be simple and robust. They must also satisfy the acute requirements of chaotic environments where resources will be inadequate for the necessities of immense proportions and tasks must be swiftly prioritized in the face of inadequate useful information amidst abundant data. Additionally, they must be suitable for the use of people who might be in shock or in deep distress because of large scale of human and material losses. The systems must also be designed to work in environments where communication lines are disrupted and power can only be supplied by mobile generators.

Based on the body of knowledge about information system for crisis response and Human-Computer Interface (HCI), this article will seek to develop appropriate user interfaces to be used for authorities and general public in case of a major disaster.

Keywords: Human-Computer Interface (HCI), Emergency Communication System (ECS).

INTRODUCTION

Eastern Marmara region of Turkey was hit by two major earthquakes on 17 August and on 12 November 1999, with magnitudes of 7.6 and 7.4. These disasters claimed in excess of 20,000 lives, destroying at the same time many homes, public and private buildings as well as an important part of the infrastructure. Since the region is an important industrial area, there were also huge financial losses. For two or three days after the first earthquake, there was hardly a clear idea about the extent of the losses due to the collapse of the communications and the transportation infrastructure. While thousands were waiting for rescue teams, medical aid, food and water, as well as instructions on what to do, millions on the other hand were trying to hear from their loved ones in the area. The need for an emergency information system was severely felt. That need is even more acute now in the face of the threat of a 7+ magnitude earthquake expected to hit close to Istanbul, a metropolis of around 15 million inhabitants, in future.

In an article that was published exactly one month after the first earthquake, Barka (1999) had warned that the event might trigger another earthquake in Duzce-Bolu region which came only after two months. Several authors currently warn that the two earthquakes should be a source of concern for Istanbul, because the main fault line (North Anatolian Fault Line) on which these two earthquakes and previous similar ones occurred is only about 10 km from the southern shores of the city. According to Atakan et al. (2002) and Hubert-Ferrari et al. (2000) there is reason to expect that the 1999 earthquakes might have a triggering effect westwards on the fault line towards Istanbul. Sengor et al. (2005) estimate "a major event" in the next half century with an approximately 50%

probability around Istanbul. According to Parsons et al. (2000) the probability of the Istanbul earthquake in the next decade (after 2000) is 32% (±12) and in the next thirty years is 62% (±15). The city had several destructive earthquakes in the history and one can expect the same in future. An important advantage of the 1999 earthquakes was that Istanbul was not extensively affected by them and provided all kinds of support to the region which was only a few hundred kilometers away. The opposite is unlikely in the Istanbul earthquake, because the periphery provinces will probably fall short of having means and resources to support the population of Istanbul in case of a major disaster.

Earthquakes have a distinct characteristic which differentiates them from other natural disasters. There is virtually no warning period. For other natural disasters such as hurricanes and tsunamis, there is a warning period from a few hours to a few days. So, emergency preparedness plans can be immediately initiated to perform mitigating actions to save lives and partly property, before the disaster actually strikes. For earthquakes though, there is no such warning. Building strong structures and making plans for post-quake actions notwithstanding, all preparedness is for recovery after the event.

As part of the preparedness for disasters of large proportions, it is important to develop information systems for use by authorities and general public. Such information systems may be the only link of the isolated communities to the outside World, and may be a matter of life and death to many individual people. The requirements for such systems may vary somewhat depending on the context, the scenario and different user types. But there are general requirements valid for all such systems, each of which may be called an Emergency Communication System or ECS.

Based on the body of knowledge about information systems for crisis response and human-computer interface, this article will seek to develop appropriate user interfaces to be used for authorities and general public in case of a major disaster. The article does not aim to analyze and provide recommendations for the interface of the available ECS like Sahana (that will be described below); rather it seeks to develop some guidelines for developing effective HCI for the ECS. As explained above, such an undertaking is particularly important for Istanbul that can be hit by a major disaster.

POSSIBLE USE OF ECS IN THE FUTURE ISTANBUL EARTHQUAKE

As experience shows from the two earthquakes mentioned above and others, a large earthquake brings with it total or large scale breakdown of infrastructure and essential services in the affected area. These include the transportation and communication networks, public utilities (power, gas, water, sewage, garbage disposal), security services, health care services, especially rescue, emergency aid and burial services. Also the collapse of the banking and commercial environment severely restricts the purchase and general availability of essential goods and services by the public.

The main reason for the loss of lives in the 1999 quakes was the sub-standard apartment blocks many of which collapsed completely during the earthquakes. It is known that the quality of the construction in Istanbul is not better than the region where 1999 earthquakes occurred and according to some estimates about 5000 apartment blocks (many of which are already identified) will totally collapse in case of a major earthquake. Ideally, those blocks should be immediately evacuated, demolished, and re-constructed. However, it is difficult to find resources for such an endeavor in the country which is under a huge debt burden. Like most developing countries, tangible causes such as lack of resources and intangible conditions such as fatalism prevent taking a proactive stance in the face of disasters.

In a major disaster it can be envisaged that many small communities will become isolated from the outside world and from each other except for walking and face to face communications. If electricity can be generated locally or on-site, then radio and satellite TV can provide one way information transmission to the isolated communities. These isolated communities may consist of villages, small districts, city or town quarters, or a street or even part of a street.

Based on the aftermath of the 1999 earthquakes a possible scenario for the first few days of the disaster is as follows. The scenario is by no means complete; only the attributes that are related to the ECS are hypothesized:

TABLE 1. Scenario for the first few days of the possible Istanbul Earthquake.

	Day 0	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
Power	No power	No power	Some parts of the city	Some parts of the city	Full	Full	Full	Full
Traditional	No	No service	Some	Some parts	Full	Full	Full	Full

Internet	service		parts of the city	of the city				
Internet through Wi-max	No service	No service	No service	Some parts of the city	Some parts of the city	Full	Full	Full
ECS	Possibly not available	Disconnected ECS databases	Merging ECS	Full service ECS	Full service ECS	Full Service ECS	Full service ECS	Full service ECS

According to the scenario, it is unrealistic for any kind of ECS to be operational in the first few days of the disaster even if electricity is provided by local generators. Later, it can be possible that individual, disconnected systems will start compiling their databases and those individual units will have to be merged in a central database. Sahana that has been developed after the Asian tsunami disaster on 26 December 2004 could be an ideal solution for this effort (Currion et al., 2007) (see www.sahana.lk). Sahana was developed in Sri Lanka and it is a freely available open source system that has received Open Software Foundation's award for social benefit in 2007. Like the system itself, its components such as MySQL database, PHP programming language, and Apache Web server are all open source systems. The organization responsible for the system and its continuous development efforts is Lanka Software Foundation. Sahana offers very useful facilities during a disaster including the following modules:

- Missing Person Registry
- Situation Awareness
- Organization Registry
- Request Management System
- Volunteer Management
- Inventory Management

The system was also successfully implemented in the earthquake disaster in Pakistan in 2005, Southern Leyte mudslide disaster in Philippines in 2006, and Yogjarkata earthquake in Indonesia in 2006.

Sahana's appeal to developing countries is manifold. Firstly, it is freely available through GPL (General Public License). In other words, there is no need to spend hard-earned (or borrowed) foreign currency for the software. If there are some non-governmental or professional organizations that plan to develop ICT-based disaster preparedness systems, they are usually financially so weak that they have to count every penny. Further, being aware of robustness and security of Free and Open Source Software (FOSS) as opposed to proprietary software, ICT professionals' organizations are usually strong advocates of these systems.

Secondly, most developing countries have collectivist cultures (Hofstede, 2001) as opposed to individualistic cultures that reign in industrialized countries. Unlike today's individualistic cultures that tend to associate every service and material with money, collectivist cultures may be more inclined to expect some services and materials that are related with the common good as free. Rampant piracy of proprietary software in developing countries can also be seen in this respect. Concentrating on the ICT for development issue rather than the difficult ethical issues related to this matter, Mansell and Wehn (1998, p.142) assert that software piracy in developing countries has some positive outcomes such as helping to develop a local software industry.

Thirdly, knowledge of English is not common in developing countries and local language is a must in all types of software that has to be used by ordinary people rather than well-educated professionals. Although Sahana comes in English language as default, it offers a facility that enables localization and translation of screens to the local language. Further, the entire HCI can be redesigned according to the local flavor since the system comes with its source code.

A significant reason of Sahana's importance to the developing countries stems from the fact that natural disasters are more devastating and claim more lives in developing countries compared to developed countries. There are several reasons for this: Industrialized countries usually tend to take a more proactive stance in disaster preparedness (a notable exception is the hurricane Katrina in the US); they have more developed infrastructure to mitigate the effects of the disaster; and they have better emergency services during or after the disaster. For example, Japan is an earthquake country and it has a well-developed preparedness infrastructure for the disasters. Earthquakes of the same magnitude claim much more lives and are more devastating in developing countries compared to Japan. Although computer-based information systems cannot prevent the devastation to the buildings, and physical infrastructure, they can be extremely useful for softening the effects of the disaster on the survivors. This can be mainly accomplished partly by effective allocation of aid resources during and after the disaster as well as establishing contacts and providing other information. The contacts can be among the victims as well as between aid workers and domestic and international aid providers.

A GENERAL LOOK AT THE REQUIREMENTS OF AN ECS

First of all, an ECS must be absolutely reliable. That is, it must always be trusted to work even if the regular public communications infrastructure collapses. Additionally, the system must be highly available. These are important, because users' trust of systems is fragile; systems and interfaces with inaccurate data or high downtime are doomed for disuse following a short period of frustration.

So, physically an ECS must be based on a separate, robust infrastructure, preferably independent of the wired telecom or GSM networks. One proposal could be to use a long range (HF or VHF) wireless based system. But the bandwidth requirements of an ECS would far exceed the limited voice grade capacity of such channels. So, a satellite based communication system seems to be the best, and probably the only alternative.

We will not dwell on the technical requirements and architecture of an ECS here except to note that enough bandwidth must be available for several voice and a possibly a few video channels operating bi-directionally. Furthermore, the ECS is assumed to be located within a safe and secure structure with power available from on-site possibly portable generators.

Such systems and their interfaces with users must be simple and robust. They must take into account the acute requirements for chaotic environments. They must also be suitable for use by people who might be in shock or in deep distress because of large scale human and material losses. Considering that resources will be inadequate for the necessities of immense proportions, and tasks must be swiftly prioritized in the face of inadequate useful information amidst possibly abundant data.

Two general types of users can be envisioned with further division within each type, and elaboration of communications between the different subtypes. One type is the group of officials who have been appointed to manage and to use the ECSs in emergencies. They would be extensively trained to use the system including retrieval of stored information but more importantly communication with national or other authorities. The training would have to be repeated periodically to assure reliable and effective use even when the users are under great stress.

The other general type of users is the rest of the population, or the man in the street, who may or may not have used a computer or an interactive electronic system at all. For this group the user interface must especially be simple, clear and robust. This group may be communicating with likes of themselves or with officials or experts trying to help from outside the region.

Response times are important for both types of users but especially the second or novice group. Considering that users would be impatient and stressful, if the response is not coming within a second or two, the systems must inform the user when an answer is expected and assure them that work is proceeding and the system is not locked. This requirement has implications regarding both the bandwidth and the user interface.

HUMANS' INTERACTION WITH COMPUTERS

Humans interact with computers through their sensory organs. The most common type of human-computer interaction is the somatic sensation (touch/press of keyboard and point and click systems) for input to the computer and vision for output from the computer. Input also requires the latter for coordination of the former. Implementation of other sensory organs may also be required for less common types of interaction. Audio is frequently used for alarms and similar situations requiring urgency. Audio may also be the preferable choice in case of novice users giving them instructions on what to do.

Requirements analysis is an important step in all information system development methodologies. This step is performed in the initial phases of the development and it determines the later phases of the development as well as the information system itself. Requirements analysis must also be performed for the interface of the system with humans, because every information system is developed for a specific user population and for specific purposes some of which may have special requirements.

Shneiderman and Plaisant (2005) list four goals for conducting the requirements analysis of an effective information system. The first goal is to *ascertain the users' needs*. In other words, the interface must be suitable for the tasks and subtasks that the information system must carry out. *Ensuring proper reliability* is the second goal. Reflecting the proper working of the information system, displayed data must reflect the database contents accurately and updates must be applied correctly. Additionally, the system must be highly available. These are important, because users' trust of systems is fragile; systems and interfaces with inaccurate data or high downtime are doomed for disuse following a short period of frustration. Thirdly, *the interface must provide appropriate standardization*, integration, consistency, and portability. These are important, because they have important implications on the learning curve as well as having the potential to mitigate the likelihood of human errors. And lastly, the project, especially the human interfaces of the system *must be completed on schedule and within budget*. Although all of these four broad set of requirements are applicable for not only the human-computer interface, but also for the entire information system, these requirements have special meanings in designing the interface.

Today's computers provide mainly two types of interfaces, namely command line and Graphical User Interface (GUI). Since the syntax of the command as well as the order of the command and its parameters must be accurate, command line is not an ideal type of interface for novice users. Further, free navigation on the screen is not possible because the user has to perform the input command in the position determined by the computer. This position is formed by the top-to-bottom and left-to-right queue of the previous input and output. In other words, the computer has the control of the user interface in terms of navigation in command line systems. These characteristics of the command-line interface make it totally unsuitable for use in an ECS, because most of the users will be novices with substantially reduced learning abilities due to the distressed environment.

So, GUI is the preferred mode of human-computer interaction for both expert and novice users. Unlike the command line concept which is usually monochrome, in the GUI concept the entire screen is covered by a matrix of large number (eg. 1024 * 768) of pixels (picture elements) which can take a number of predefined colors. The screen designer can use the screen freely, in other words input and output positions as well as their forms and colors can be determined by the designer. Navigation on a screen or among the screens can be performed by the point-and-click device (mouse) which is supported by the keyboard. Shneiderman (1983) coined the term "direct manipulation" for this mode of input.

Almost all GUI systems also allow the user to shift to the command line interface that appears in a window in demand. Reasons for this are manifold: Some expert users might wish to bypass time-consuming navigation; command line interface might offer flexibility for some tasks such as entering unlimited number and combination of parameters; and some advanced system operation tasks can only be accomplished by the command line interface. GUI can take several forms of interaction of users with computers such as direct manipulation, menu selection, and form fill-in. The flexibility and ease-of-use offered by the GUI make it suitable to be used in an ECS.

GENERAL HCI GUIDELINES FOR AN ECS

Designing a good interface is very important for all kinds of information systems, especially for an emergency communications system. Since the end users usually have neither interest nor knowledge about the technicalities of the system, the interface *is* the system for them. Further, although the general reliability and accuracy of the information system is usually regarded to be of utmost importance, interface is a symbolic gate that acts as a tool to attain that reliability and accuracy.

In the list by Schneiderman and Plaisant (2005) for the three pillars of HCI design, the first is given as guidelines, documents and processes, coming from theories and models. The second pillar consists of the software tools to construct an HCI, and the third pillar is the testing or experimental evaluation including expert reviews. These guidelines are essential for a good start for design.

Smith and Mosier (1986) give five high level goals as guidelines for data display. The first is consistency of the display, that is, all the terms, graphics, colors and other format should be standardized and available for explanation and control. The second guideline stresses the efficient assimilation of information, implying a clear uncluttered meaningful format. The two guidelines together are very important for users under stress, who do not necessarily have the time to think and decipher the display. Abbreviations should be avoided for sake of clarity, unless quite obvious or repeatedly used. In order to introduce familiarity and expose the general population to the use of an ECS, TV or billboard advertisements may be employed from time to time. The third guideline recommends minimal memory load on the user. It must be assumed that the short-term memory of users under stress is especially weak and that they cannot be expected to remember data from one screen to the other. As the fourth guideline, compatibility is recommended between data display and data input, such as output fields acting as editable input fields. This is also important for an ECS for which the users must have a high degree of concentration on the emergency tasks and should have spent minimum effort for system tasks such as navigation through screens. The last guideline concerns the flexibility of user control over the data display. Although that could be a good feature for expert users, such a feature could be counterproductive for novice and stressful users.

As part of the basic principles of display design, Schneiderman and Plaisant (2005) offer eight "golden" rules. Reviewing them for the case of an ECS, one finds certain ones more applicable and important than others. Consistency and reduction of short term memory load which are very important for ECS have been already mentioned. Catering for universal usability includes needs of the diverse users. While novice users need more explanation, shortcuts and faster pacing may be more important for expert users. Information feedback becomes especially important for novice users, because they are not aware of the inner workings of the ECS and they require feedback for trust in the system that all is proceeding as expected. Prevention of errors is again very important, not only for effective use of the system but also for trust in the system. Especially user input errors, must always be checked, predicted as much as possible, and either automatically corrected or fed back to the user for correction. User errors must never be allowed to bring down the system, or steer it off course to meaningless ways. That includes means for easy reversal of actions which is one of the eight golden rules. Two of the rules apply more for the experts than for the novice users. One is that long dialogs should be designed to yield closure. The other golden rule is for support of internal locus of control.

Carver and Turoff (2007) introduce the concept of *cognitive absorption* that they find relevant with the Emergency Communication Systems. The concept is borrowed from the psychology discipline and has already been introduced to the Information Systems literature before (Saade and Bahli, 2005; Agarwal and Karahanna, 2000). Carver and Turoff interpret the concept with the following dimensions:

- Role players feel they are exercising control.
- High degree of concentration, ignoring everything that is not relevant.
- Using improvisation or unconditional ways to appraise information and formulate decisions.
- Senses of challenge, curiosity, and enjoyment.
- High motivation.

Building on Hansen's (1971) "know thy user" dictum, Shneidermann and Plaisant (2005) categorize three types of users according to their skill levels. The first level is *novice or first-time users* who know little of computers at all or who are experienced in computers, but not very knowledgeable about the specific task or the interface. In the second level stand the *knowledgeable intermittent users* who have a good command of the systems and their interfaces but use them only from time to time. Hence, they need some recall time for using the systems with full efficiency. The third level involves *expert frequent users* who are thoroughly familiar with the task and the interface concepts. Most of the users of an ECS will either be in the first or the second level in the critical initial phases of the disaster. Only after some learning period which can prove to be very costly, most users will be in the third level.

There have been a number of other publications in recent literature on emergency response information systems. More specifically, the March 2007 issue of ACM Communications, has a special section on the topic (Van De Walle and Turoff, 2007). In one of the papers there, Carver and Turoff (2007) treat the human and the computer as a team and emphasize a user centered approach in HCI design, not one driven by technology. In another paper, Manoj and Baker (2007) stress that reliable communications in an ECS must address not only technological but also sociological and organizational issues. Sahana, already mentioned above, is the subject of another paper (Currion, De Silva and Van De Walle, 2007) where its open source software is shown as another exemplar aspect of an ECS. There is also an international conference held annually on this topic by ISCRAM, International Community on Information Systems for Crisis Response and Management. The last (fourth) ISCRAM conference was held in 2007 in Delft, The Netherlands.

An ideal ECS should be web-based with proper security. It should ideally be used by not only in the disaster area, but also all over the country and even all over the world by people and organizations who want to get the news about the disaster and provide relief and help. Table 2 shows the possible user community for an ECS. *Survivors* are the survived members of the population who are affected by the disaster. Survivors might have lost their loved ones and might themselves have some injuries. It is very possible that they are highly distressed and confused. As a result, they will not be in an ideal mind set to use computers. Competition for scarce resources might lead to conflicts which also might have an adverse effect in the ability to use computers effectively. *Rescue workers in the disaster region* are volunteer individuals or employees of rescue organizations such as Red Crescent. They might either be from the local population or not. They need to be very highly motivated and concentrated in an environment of excessive work load in extremely long working hours. *Rescue workers at remote* are typically volunteers and employees of relief organizations such as Red Cross or officials of national government organizations. If the disaster is very severe some relief might also come from other governments which extend the user population to the officials of the foreign governments. *Friends and relatives at remote* will possibly be among the frequent users of the system due to their concerns about their loved ones. This concern might also lead them to raise funds. If the disaster is very severe, concerned *individual aid donors* within the country and all over the world will be using the system to get news and to donate funds provided that the ECS have such a facility.

TABLE 2. User types of an ECS and the attributes of HCI for each type.

	Survivors	**Rescue**	**Rescue workers**	**Friends and**	**Individual aid donors**

		workers in the disaster region	**at remote**	**relatives at remote**	**at remote**
Skill level for using the ECS	*Novice or first-time,* possible delegation of computer usage to others	*Novice or first-time/knowledgeable intermittent*; later *experts*	*Novice or first-time/knowledgeable intermittent*; later *experts*	*Novice or first-time;* later *experts*	*Novice or first-time*
Workload	Not much	Extremely heavy	Heavy	Medium/Low	Low
Motivation	Very high	Very high	High	High	Low
Stress level	Extremely high	Very high	High	High	Low
Awareness of high cost and irrecoverability of error	N/A due to the victims' confused state of mind	Very high	Very high	N/A	N/A
Satisfaction level at the end	N/A due to the victims' confused state of mind	Very high	High	High	N/A
Requirement for prioritizing items in information overload	N/A due to the victims' confused state of mind	Very high	Very high	High	High
Requirement for converting tacit knowledge into computer's codified knowledge	N/A due to the victims' confused state of mind	Very high	Very high	Low	Low
Knowledge of the events in the immediate disaster area	Excellent	Excellent	Low	Low	Low
Knowledge of the events in the big picture	Low/Medium	Low/Medium	High	High	Low
Requirement for fast decision-making and prompt action	N/A due to the victims' confused state of mind	Very high	Very high	Medium	Low
Requirement for trust to the others	Very high	Very high	Very high	High	Medium
Requirement for high degree of concentration	N/A due to the victims' confused state of mind	Very high	Very high	Medium	Low
Ability to perform in conflict situations	High	Very high	Very high	Medium	Low

Most of the parameters in Table 2 such as the level of workload and requirement of prioritization of items thereof, concentration, trust, ability to perform in conflict situations require different types of interface. Since an ECS should be used by a diverse community of users that might have varying degrees of those parameters, its interface should ideally be multi-faceted. In other words, the interface of an ideal ECS should have different interfaces for different types of users. For example, the interface that should be used by the victims should have minimum level of data and it should be very easy to navigate so that no teaching would be necessary. This, however, does not mean that the interface(s) should be totally different from each other. On the contrary, the screens and navigation within and among the screens should conform to a pre-defined standard and the style.

CONCLUSION

Disasters cannot be prevented, but the damage and destruction they cause can be relieved to some extent by humans. Thanks to the information technology, this relief process might be much more effectively performed through a new kind of software which might be called Emergency Communication Systems. Sahana, which was successfully implemented in the major disasters of the last few years, is becoming a standard ECS all over the world. Since it is an open source system that is being developed by collective labor with no expectation of return, it fits well with the humanitarian nature of the relief efforts for the people who are struck by disasters.

Sahana has already an effective interface that conforms to the requirements for an effective ECS. It is neat, and it uses minimum level of unnecessary picture, animations, sound, etc. which require high bandwidth. These multimedia components might prove to be very costly in a disaster environment where the Internet infrastructure might be severely damaged and every bit in transmission counts. Sahana, however, needs to be further developed. It is possible that Sahana will be a much more sophisticated system in future. One of the requirements of this sophistication is to cater the needs of its diverse user population. This article can be a source for developing even more effective human-computer interfaces for the diverse users of the system.

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