Designing a fire incident response information support system

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Abstract— **This paper presents a computer-based system for a fire incident response information support system (FIRISS). FIRISS is designed to allow contextual information sharing among a firefighting response team during a fire emergency. The FIRISS is implemented using Microsoft .Net tools with Visual Basic as the primary software driver. The interface is intuitively easy to use with the information contents reflecting only relevant information with aids of menu icons for weather conditions, telephone dial pads, capability for broadcast and play-back of videos, and dialog boxes for textual communication.Thematic knowledge in human-computer interaction, cognitive systems engineering, and visual analytics are used.**

***Index Terms*—Collaborative work, Cognitive systems engineering, Decision support system, Emergency response, Information management.**

I. INTRODUCTION

The characteristics of fire incidents and their responses are traditionally known to be complex. Solutions to aid the fire fighters are always evolving in response to criticality, availability of modern technology, and the state of information gluts and fluxes. These fire events are risky and often result in many human deaths and ecosystem disasters. In general, the management and control of fire when it happens belong to a class of complex problems [1]. Zack [2] have noted four characteristics of a complex problem domain:

1. *Uncertainty*: not having enough information or the unreliability and trust of existing information;
2. *Complexity*: the problems of understanding the interactions of the firefighting team. For example, who does what and when?
3. *Ambiguity*: not having a conceptual framework for interpreting information about the context which the fire occurs;
4. *Equivocality:* having several competing or contradictory conceptual hypotheses from the first responders.

Firefighting information space is also subject to at least two types of uncertainties [3]: aleatory and epistemic. Aleatory uncertainties are characterized by randomness, such as vehicle sensor noise. They are inherent, irreducible and unpredictable in nature. Epistemic uncertainties are subjective and arise from limited or imperfect knowledge of the firefighters. Epistemic uncertainty can be attributed to human decision makers who try to estimate operational information needs as fire events unfold.

Typical manifestations of uncertainties in the firefighting domain can be attributed to four factors:

(a). *Impreciseness*: Here, people qualify situations by degree of granularity such as “the temperature is excessive;”

(b). *Incompleteness*: First responders in the fire site rarely have a complete information about or situation awareness events and activities over a time horizon;

(c). *Inconsistent*: fire incidence investigators are rarely consistent in their field observations and estimates;

(f). *Unknown*: Information object may be unfamiliar or unknown when the firefighters are in contact with the reality at the incident point [4].

II. RATIONALE

Any response to fire requires speed and agility in collecting, processing, and disseminating information between all the emergency players that consist of, the firefighters, police, medical paramedics, first responders, and the mutual aids resources. Fig 1 illustrates this situation. In Fig.1, information about incident events are distributed from ERC2 (Emergency response Command & Control) to various agents who are geographically dispersed. When the service agents converge, they work to solve a singular problem of saving lives and containing fire spreads.

From Fig 1, an emergency domain can be viewed as a collaborative enterprise system where agents interact with each other during a chaotic and unpredictable event such as a fire outbreak. Because of the unpredictable nature of information characteristics in the emergency domains, the agents responsible for planning, decision making and execution should receive some form of analytical support. Such support tools will help to collect and manage information during an emergency response planning cycle.

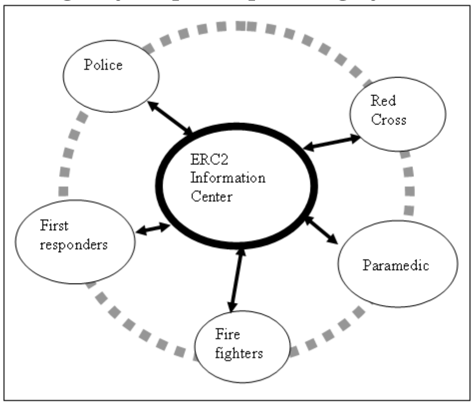

Fig.1.The distribute structure of an ER team

In the FIRISS, the distributive information network of many work structures are connected by routers and gateways (these can be C2 influences, structural relationships, roles and functions). These routers and gateways can be described conceptually, such as the relationships between the police department and the fire chief of a city.

Information management is the major key to an effective fire control [5]. An information management support system (IMSS) will help the fire team as follows:

1) Scalable, distributed, and collaborative: To enable real-time ubiquitous collaboration of all disaster response entities, all platform computing elements and the agents (humans, machines, and tactical objects) architectures should allow for the ability to scale-down or scale-up information needs based on the fire conditions.

2) Decentralized, modular context inference for intelligent, coordinated and mutual-aid response: Information coming from remote devices, sensors or environments should be preprocessed at their origin as far as possible and deliver only the essential and relevant information to the firefighters on the field.

3) Reduction to relevant input: To shorten incidence and response times, the inference time and the amount of low level information has to be reduced to a minimum.

III. FIRISS DESIGN

A. Cognitive Systems Engineering and Human-computer Interaction Tools

FIRISS design is influenced by two inter-related thematic disciplines: Cognitive Systems Engineering (CSE) and Human-Computer Interface (HCI), respectively. CSE is a discipline that allows system designers to represent the human mental model of a work domain with a corresponding human information processing requirements [6]. This internal representation allows it to make predictions, assess possible courses of action, and evaluate consequences without resorting to trial and error. HCI is a discipline that allows system designers to represent interface- and interaction-modalities so as to allow the humans to interact with computers more naturally [7].

Cognitive task analysis (CTA) and work domain analysis are the two major analytic tools in CSE and HCI used in this project. Both tools are used to map human information resource requirements to allocated tasks. The CTA procedure suggested by [8] is employed. This involves the:

i). Development of a cognitive task process of the firefighting teams;

ii). Development of an information flow model using task diagrams and information processing flow diagrams;

iii). Performance of a misconceptions analysis by reconciling convoluted terminologies and stratification of intelligence products according to the stakeholders; and,

iv). Performance of a structural knowledge analysis by developing conceptual maps or cognitive network representations of each fire fighter. Fig. 2 illustrates a typical task-based firefighting organization. Here, the command and control (C2) center is responsible for organizing all response to disasters such as the fire outbreaks. Upon receiving an incident report, the C2 notifies the first fire response agencies nearer to the point of incidence. Table 1 shows example information derived from a CTA.

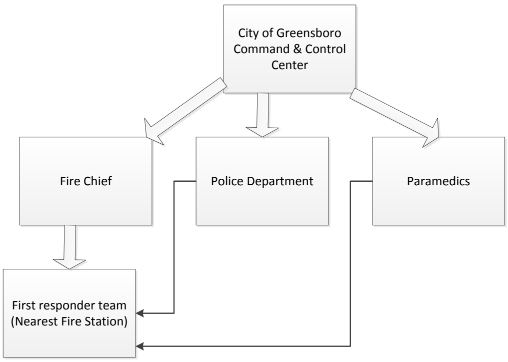

Fig 2. Organization of a firefighting team

B.Decision-centric Interface for Enhanced Situation Awareness

FIRISS uses a decision-centric interface principle [6]. A decision-centric interface supports task performance in at least four ways. First, only relevant information is sent to the node that needs it. Second, a display tool is designed to minimize information overload the human users. Third, shared information is made available to many dispersed users using the concept of a common operating picture. Forth, information is presented to the field firefighters to optimize their situation awareness. The interface also uses a configural display as shown in Fig. 3. According to [9], a configural display is a display that represents information about functionally related system components in such a way that the operator can extract information about individual components at a local level and system level.

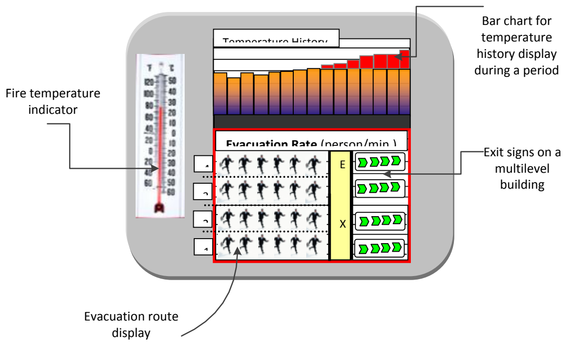

Fig. 3. An example configural display

Table 1. Typical tasks performed by a firefighter teams.

Responsible Unit	Sample Tasks
Command and Control (C2)	Dispatching, record keeping, resource management.
Fire Emergency Response Team	Point of incidence control and management, search and rescue of victims, fire management and containment, fire team resource management, victim assistance, and secondary emergency services.
Emergency Medical team	Administering first aid, transport patients to the hospital or health clinics, conduct initial triage, perform medical emergency, and help to rehabilitate patients to gain good health status.
Police security Team	Secure and condone area of incident, collect evidence, direct traffic, control possibility of lootings and other criminal activities, and provide public safety.

IV. SAMPLE INFORMATION MANAGEMENT IN FIRISS

A. C2 Information Management

The first screen is for the C2 information management. (Fig 4.). C2 has access to all in-coming information about incidents. For example, when a call comes in, the C2 staff can identify caller, record the necessary information, and, use a Global Position System (GPS) to locate the area of interest. This information is used for planning and issuing task orders to all the fire teams.
The textbox of the dial-pad allows the staff to record incident type, incident number and incident date.

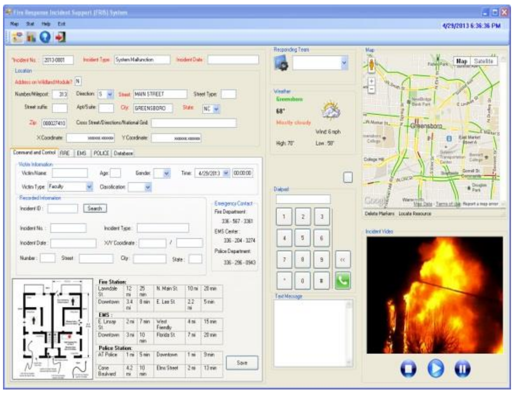

Fig.4. Sample screen display for C2

B. Firefighter Information Management

Fig. 5 illustrates the information management screen for the firefighter unit. The display gives the building layout with the red dot providing a clue to the fire location. The emergency severity codes, resource locations, report data, and the current status of the incident are displayed

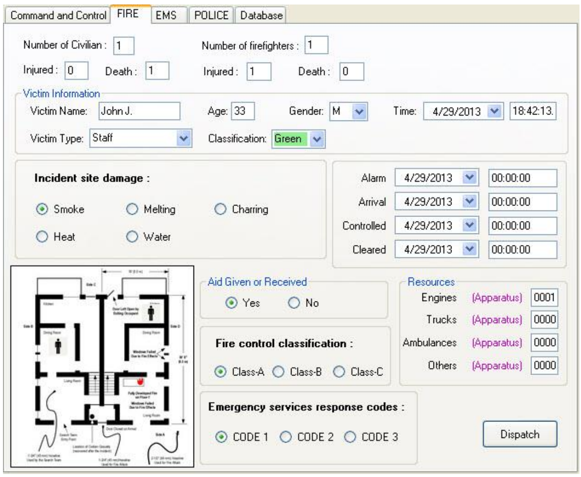

Fig. 5. Sample screen display for firefighter unit

C. Emergency Medical Paramedic Information Management

The information displayed to aid the medical team consists of the victim's personal vital data such as age, health status, gender, and the types of health problems likely to be encountered from the fire event. These could be hyperventilation, burns, and cuts. The information on the first aid treatments and diagnostic profiles are used to make ambulatory decision making of the victim to the hospital.

V. LABORATORY VALIDATION

The efficacy of FIRISS was evaluated with a Tabletop Emergency Response Simulator (TERS) used by emergency response personnel. Five teams (C2, Fire, Police, Paramedic, and First Responders) with two members each were used and collocated in the Human-Machine Systems Engineering Lab. The machine-to machine (M2M) connectivity was enabled via internet as shown in Fig. 6. The M2M interface was launched by C2 who then waited for some delay time for connection with other machines. The firefighter team set their respective geolocation with the Google Earth Map. The C2 then received and confirmed the geo-location information from the team leaders with their remote laptops.

The message box of both interfaces displayed all communication logs such as incident location, distance from respective locations, possible events that will delay travel on their paths, location of incident building, location of fire hydrants and exits, including the building layout (Fig. 7).

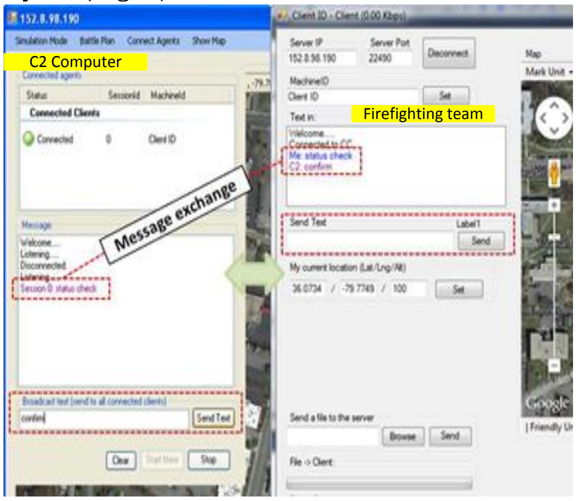

Fig. 6 Sample M2M connection for FIRISS

After every exercise, the participants completed a questionnaire designed to measure FIRISS usefulness as emergency information management system. The perception of FIRISS usefulness were rated on six metrics: M2M connectivity delay time, situation awareness (SA), information content, information organization, ease of use of interface, and the overall usefulness to their respective tasks. A subjective scale of

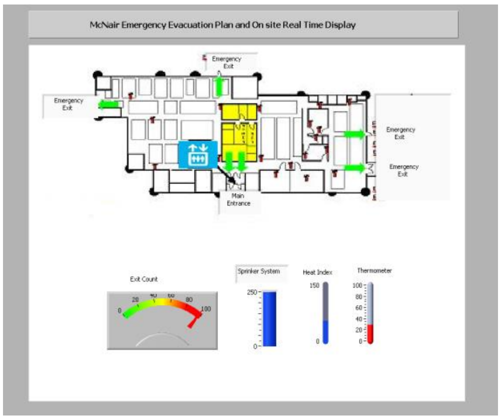

Fig. 7 Floor layout with point of incident

1-10 was used, with 10 meaning very useful and 1 = not useful at all. Members of each team and the leader rated FIRISS during each exercise session. The average scores were computed and displayed using a radar plot (Fig. 8). A radar chart is a graphical method of displaying multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point.

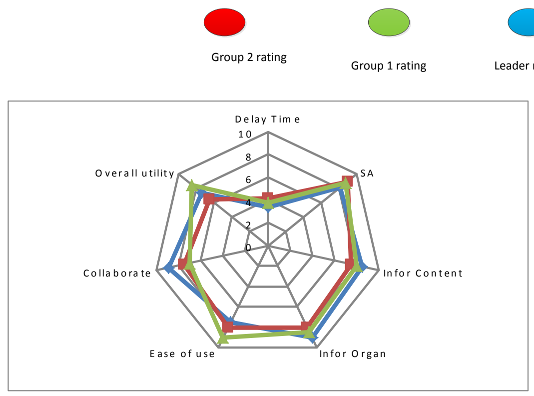

Fig. 8 A radar plot of rated performance

As shown in the radar plot, the ease of use of FIRISS interface was greater than that of the average rating by the experts (Leaders). Information contents, information organization were rated high by the Leaders, while situation awareness, collaboration, and the overall utility of FIRISS for fire incident management had equal ratings between the Leaders and the team members. More experiments are needed to conduct more statistical analysis.

VI. SUMMARY AND CONCLUSIONS

FIRISS is a prototype system designed to support information management in an emergency response domain. Firefighting was used as an example domain. The FIRISS project was implemented using Microsoft .Net tools with Visual Basic as the primary software driver.

The interface is intuitively easy to use with the information contents reflecting only relevant information. For example, menu icons for weather conditions, telephone dial pads, capability for broadcast and play-back of videos, and dialog boxes for textual communication. The interface model is built using Goals, Operators, Methods, and Selection rules (GOMS) metaphors, a kind of specialized human information processor model for human-computer interaction observation [10]. FIRISS also has the capability for aiding in route management using the shortest route algorithm.

At the end of a fire session simulation, FIRISS allows the C2 staff to review an after-fact report as shown in Fig 9. The report generates statistics on the number of victims hospitalized, death, rescued, and, other conditions that affected firefighting efforts. For the future project, we like to transition FIRISS for mobile device applications.

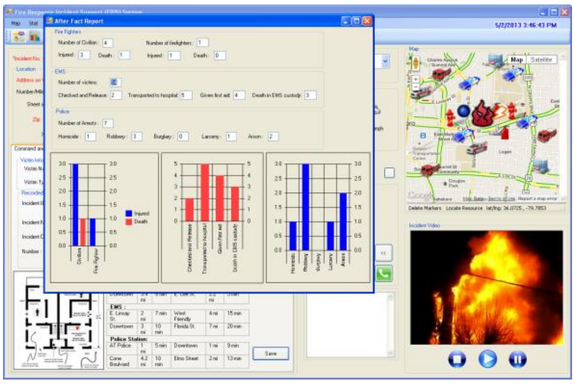

Fig 9. A sample screen of after-fact report

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BIOGRAPHY

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