DYNAMIC INFORMATION MANAGEMENT DURING FIRE EMERGENCY RESPONSE

Raj Prasanna

Business School, Loughborough University, United Kingdom[1]

Lili Yang

Business School, Loughborough University, United Kingdom

Malcolm King

Business School, Loughborough University, United Kingdom

Keywords

Emergency response, dynamic information, first responder, information requirements, software interfaces

Abstract

Currently in the UK fire tenders carry computer terminals stored with static information such as building locations, fire hydrants and building plans. However, when the first responders arrive at the site of a fire, they have very limited access to the real time dynamic information such as environmental conditions within the buildings, status of the causalities, resource requirements and the locations of various hazards. These limitations make the dynamic decision making tasks of the first responders difficult and challenging. This paper explores how integrated dynamic information can be provided to the first responders in the UK Fire and Rescue Service (FRS) to overcome such challenges. After conducting extensive interviews with fire fighters and observing fire emergency response operations, this study identifies the information requirements of the first responders. Subsequently these requirements are classified against the identified responsibilities of the core members in the first responder hierarchy. Highlighting the drawbacks of currently implemented emergency response systems in UK, this study explores sharing of integrated information among the first responders in the UK FRS. Finally, this paper outlines the progress made in the development of software prototypes representing an information system capable of integrating and sharing the desired information among core members of the first responder hierarchy.

Introduction

Fire has been categorized as one of the major global disasters. In 2006, as a result of fire, 3,245 civilians and 106 firefighters lost there lives in the United States (The Overall Fire Picture – 2006, 2006). Similarly, in Germany, approximately 550 civilians and 18 fire fighter deaths have been recorded due to 210,000 yearly fire incidents (Bretschneider et al., 2006).

Corresponding Author:

[1] Loughborough University, Loughborough, Leics., LE113TU, United Kingdom, bsrpr2@lboro.ac.uk

According to the statistics published by the UK Home Office, every year there are more than 40,000 accidental house fires in England, resulting in average deaths of 285 and 9,000 burn injuries (Yang and Frederick, 2004).

Fire Emergency Response – The UK Scenario

It is evident that almost all the FRSs in the UK use the services of information systems, embedded with various technologies to support their decision making (Computerized Equipment, 2007; Fire Service Manual, 1999; Introduction to the Incident Command System, 2007; Yang, 2007). But initial investigations of literature, documentation, observations and further the interviews with fire fighting experts, reveal that the current procedures and practices of the UK FRSs failed to provide the expected level of support in decision making during the response phase of a fire. One such classical failure in decision making is the recent deaths of four fire fighters in Warwickshire (BBC News 24, 2007). These findings suggest that most of the decision support tools available for the UK fire brigades are either insufficient or incompatible.

The above identified failures and raises the issue of, why the systems are not capable of supporting the decision making during a fire emergency. Literature reveals that most of the available and ongoing information system development projects in the UK FRSs do not focus on supporting its first responders during the response phase of a fire(Yang and Frederick, 2004, Yang, 2007), but focus on supporting the command & control rooms. Although there are a few FRSs which are capable of supporting decision making up at the incident site, such systems only carry static information (Computerized Equipment, 2007). Therefore these systems do not support the dynamic decision making requirements of the fire ground officers (Yang, 2007).

Similarly significant work done in other parts of the world, in relation to supporting the first responders of a fire emergency (Jiang et al., 2004, Bretschneider et al.2006; Wilson et al., 2005) recognized the importance of providing real time information to the first responders. But none of these research efforts described the importance of sharing information among important members of the first responder hierarchy. Rather than sharing information among different members of the first responders these solutions only addressed the information needs of different specific members in isolation (Prasanna et al., 2007).

As an initial step towards overcoming above identified limitations, this study attempts to:

- Explore the information requirements of selected core members in the UK firefighter hierarchy.
- Explore how to present and share information among fire fighter during the response phase of a fire.

With these objectives this study aims to support the system designers to develop information systems capable of managing the response phase of a fire emergency. Ultimately the findings of this study will help to improve the end-user trust towards using information systems in their emergency response operations.

Requirements Collected on the Response Phase of a Fire Emergency

Initial explorations of the literature related to the UK fire fighter first responder hierarchy, and observations made on the first responder operational activates led identification of four important members in the first responder hierarchy, namely : Incident Commanders, Sector Commanders, Breathing Apparatus (BA) Commanders or Entry Control Officers, BA Wearers or Front Line Fire fighters. Apart from these core members, other job roles are considered to be commonly introduced mainly to maintain the appropriate span of control, simply so that they will reduce both mental and physical workload of the core members. Therefore any support system available or to be proposed in the future should essentially look after the needs of above core designations. Initial investigations led to the assumption that if any system is able to see to the requirements of above members, it would be easily adopted to assist any other supporting role in the fire and rescue hierarchy. These explorations further revealed that the requirements of other members of the hierarchy are a subset generated from the combined requirements of the identified core members. (Fire service manual, 1999)

Interviews conducted with the domain experts reveal that currently in the UK these important job roles struggle to make decisions due to the fact that they face greater challenges in acquiring information and sharing acquired information among themselves in a coordinated manner during fire emergency response operations.

Later, interviews carried out with subject matter experts, selected among the above identified job roles in the first responder hierarchy, led us to a successful elicitation of dynamic information requirements during a fire emergency. The accuracy these information requirements were strengthened by triangulating against the procedure and policy documents and the findings of the observations made during fire and rescue operational activity. Triangulated information requirements were later classified against each individual job role.

After such triangulation, the information requirements of different job roles in the fire fighter hierarchy are summarized as below.

<u>Information Requirements of a BA Wearer</u>

The information requirements of the front line Breathing Apparatus (BA) Wearers included essential management information requirements such as:

- information on the immediate surrounding of the fire fighter,
- information on the fire fighter's body health,
- information on causalities,
- overall contextual information on the sector they are operating in,
- information on the assigned tasks and resources.

Further their requirements revealed needs for real time alarms such as:

- out of range alarms,
- health alarms,
- evacuation alarms,
- out of route alarms relevant to an individual BA wearer
- environmental alarms on possible back draughts or flashovers.

The findings also highlighted several information needs of the BA wearers which are considered as essential to lead them to higher levels of situation awareness (SA) (Endsely et al., 2003). These higher level SA requirements can be described as:

- search and rescue root options,
- real time navigation support,
- alternative root options due to contextual change.

<u>Information Requirements for Breathing Apparatus (BA) Commanders</u>

It was evident that BA Commanders essentially have the same requirements to those of the BA Wearer. But it is important that information of all the BA Wearers should reach the appropriate BA Commander. In addition, findings highlighted several additional management information requirements such as:

- evacuation status of the BA wearers,
- current BA hierarchy and assigned profiles of the BA wearers,
- tasks assigned for a BA Commander,
- assigned resources and new resource requests,
- completed search and rescue efforts,
- status of the search and rescue efforts currently in progress.

Further the BA commander information needs include several real time alarms identified as additional alarms to that of BA Wearers:

- evacuation failure alarms,

- alarms due to unexpected root changes of the BA wearers,
- duty assignment alarms.

Apart from above additional requirements the findings also revealed several new requirements of BA commanders could lead them to higher SA:

- automated safety whistle,
- search and rescue mission planning options,
- BA team building options,
- resource allocation and request options.

These were identified as new decision support requirements of the BA Commanders in addition to that of BA Wearers.

Information Requirements for Sector Commanders

The findings showed that almost all the management information and other real time alarm requirements of a sector commander are similar to that of a BA commander. However their requirements expand to cover the respective sector of an individual sector commander. In addition the findings revealed, context forecast, determination of ventilation locations as novel higher level decision support requirement of the sector commanders.

Information Requirements for Incident Commanders

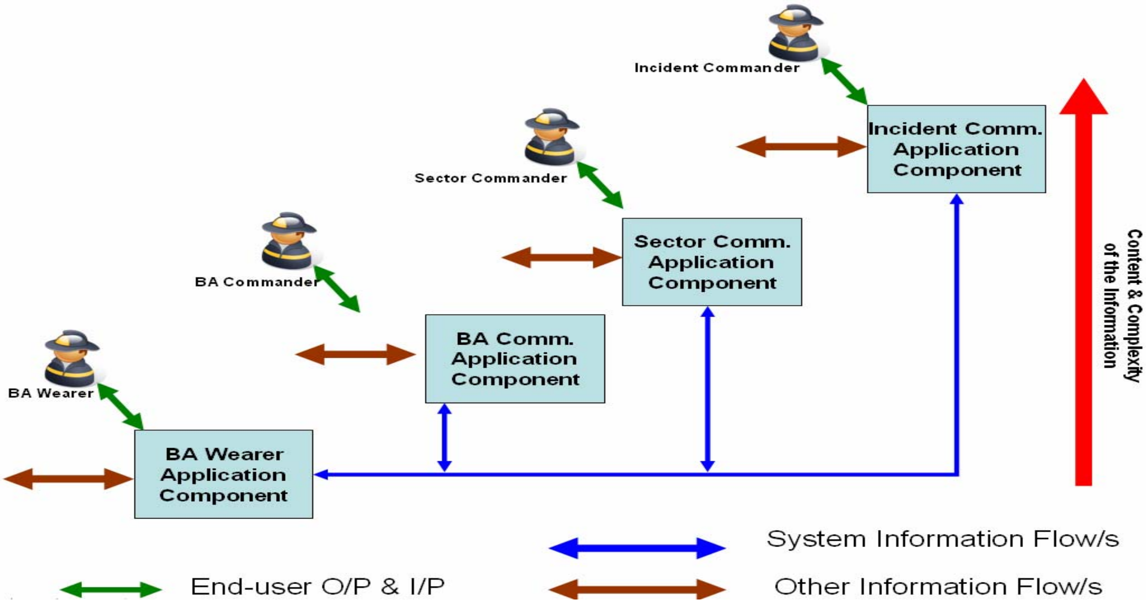
In addition to the sector commander requirements expanded across all the sectors of an incident, the information requirements of an incident commander include an incident summary report as a new management information requirement. This is a detail periodic report capable of providing overall status of the incident, inclusive of information such as number of causality being rescued, injuries, deaths, tactical mode changes, sector details, etc. Furthermore, the information requirements of incidents commanders also include new requirements of real time alarms such as resource request delay and duty assignment. In addition information to rank causality at the incident was identified as a unique higher level SA need for the incident commanders. The findings also indicated essential information requirements to improve situation awareness of the Incident Commanders to make the initial risk assessment as soon as they arrive on the site of an incident.

Information Systems Architecture for Fire Emergency Response

Based on the findings of the specific requirements of individual core members of the first responder hierarchy, and considering their nature of the operational conditions and responsibilities, this study proposes a conceptual information systems architecture (ISA). This ISA represents the coordination of information sharing and presentation of identified information needs of individual members of the first responder hierarchy. As shown in the Figure 1, this ISA identifies the importance of having a tailor made application component designed to suite the unique information requirements of each end-user. Consisting of four layers of interdependent application components this ISA recognized the importance of information sharing among different members and therefore proposes appropriate system information flows among each application component. Further the proposed ISA highlights the increasing complexity and content of the information, as when it reaches high layers of the architecture.

Based on the needs of the defined application components, efforts are being made to develop software interfaces capable of delivering the information needs to each identified member. These human computer interfaces aim to demonstrate an information system embedded with the functions of each application component. At present development of interfaces capable of demonstrating the functionality of the application component representing the top most layer of the above defined conceptual ISA are completed. Further, the developed prototype interfaces representing the Incident Commander Application Component were presented to a larger group of incident commanders and their feedback was obtained for further improvement. These feedback sessions resulted in positive signs from fire fighters towards the interfaces. Further it highlighted enthusiasm among prospective end-users indicating they had trust towards information systems to support their decision making. Surprisingly this the was opposite to our previous observations as at the beginning of this study when fire fighters believed training was the only mode of support available for their decision making during an emergency.

Figure 1: Conceptual Information Systems Architecture for Fire Emergency Response



Prototype of System Functionality

Methodology

This study selected GUI Design Studio Ver.2 as the interface development tool. GUI Design Studio is a graphical user interface design tool for Microsoft Windows environment which is used to create demonstration prototypes rapidly without any coding or scripting. It is an ideal tool for creating presentations to users and stakeholders to verify requirements and designs to explore alternatives and to evaluate different usage scenarios. After evaluating other similar tools, GUI Design Studio Ver.2 was selected due to its powerful interfaces, rapid development and easy to use capabilities.

Structure of the Prototype

It has been identified that regardless of the domain needs, it is common among the teams who operate in stressful time critical operations to perceive, interpret, and exchange large amounts of frequently ambiguous information in order to develop and maintain the SA needed for successful decision-making performance (Riley et al. 2006). Considering the importance of maintaining improved SA in time critical operations such as a fire emergency response, these interfaces aim to provide the on arrival situation awareness requirements of an Incident Commander at three increasing levels of knowledge (Endsely et al., 2003): Level1SA: Perception, Level2SA: Comprehension and Level3SA: Projection.

Level1 SA – Perception.
The first step in achieving SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. Perception of environmental elements is fundamental and essential. A lack of basic perception on important information can easily lead to form an inaccurate picture of the situation. Therefore interfaces looking after Level 1 SA will reduce the risk of formation of an inaccurate picture of the incident.

Level 2 S A – Comprehension.

Comprehension of the situation is based on the synthesis of independent Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present, to include an understanding of the significance of those elements in the light of one's goals. The operators put together Level 1 data to form a holistic picture of the environment, including a comprehension of the significance of objects and events. Therefore interfaces capable of looking after level 2 SA, adopt techniques to provide a holistic picture of an environment by integrating level1 SA information

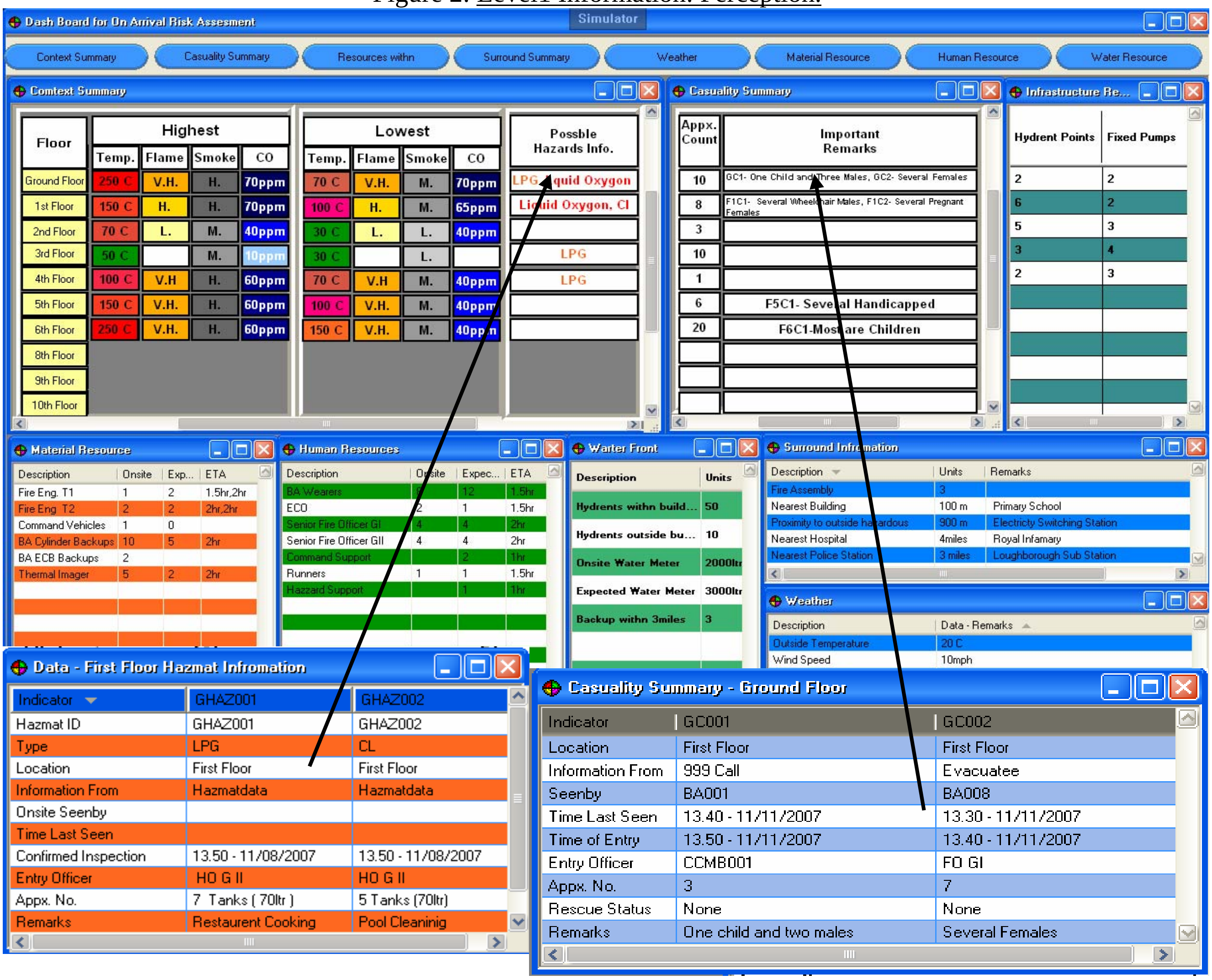
Level 3 SA – Projection.

It is the ability to project ahead the elements in the environment, at least in the very near term that forms the third and highest level of situation awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA). Therefore an interface capable of looking after level 3 SA will need to be sophisticated to forecast or predict the elements in the incident environment.

An Example of Prototype Showing the System Functionality

As an example of representing interfaces at the top most layer of the defined ISA, consider the functionality of interfaces on initial risk assessment for an incident commander. Initial Risk Assessment for an incident commander is identified as one of the crucial tasks during a fire emergency response. Therefore software interfaces supporting initial risk assessment for incident commanders are considered to be important among other interfaces.

Figure 2: Level1 Information: Perception.



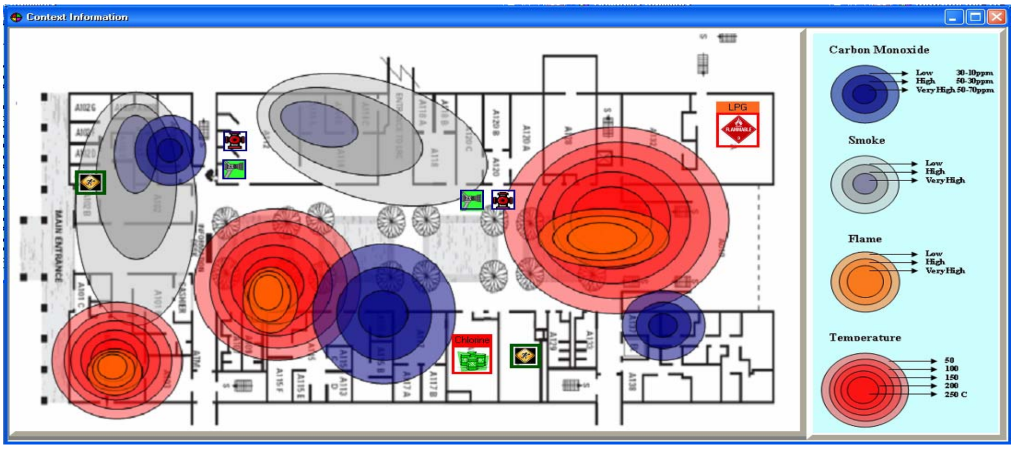
Interfaces to present Level 1 SA Information: Perception

As shown in Figure 2 this interface presents the Level 1SA Information for the incident commander. With this level of information, incident commanders are able to dynamically access summaries of the prevailing situation of an incident across eight different categories of information:

- Context Summary: information related to dynamic and static contextual parameters.
- Casualty Summary: dynamic information related the identified casualties.
- Resources Within : information related to the material resources available within an incident.
- Surround Summary: information related to incident surrounding.
- Weather: dynamic information related to weather in the vicinity of an incident.
- Material Resource :– dynamic and static information on physical resources belonging to FRS which is onsite and expected to arrive.
- Human Resource : dynamic and static information related to allocated fire officers who are on site and expected to arrive.
- Water Resource: information on available water resources belonging to FRS or others.

Under each category of information, the incident commanders will be able to receive a basic perception of a variety of parameters. For example the, Context Summary provides an overall perception on the important parameters such as Temperature, Flame levels, Smoke Levels, Carbon Monoxide Levels. Further, the context summary is also capable of providing the summarized Hazmat information. As shown, information on the context summary, casualty summary and resources within are capable of providing information across all the floor levels of the incident structure. Further the incident commanders are able to acquire more detail information on each of these categories according to his or her preference by clicking on top of each element of information.

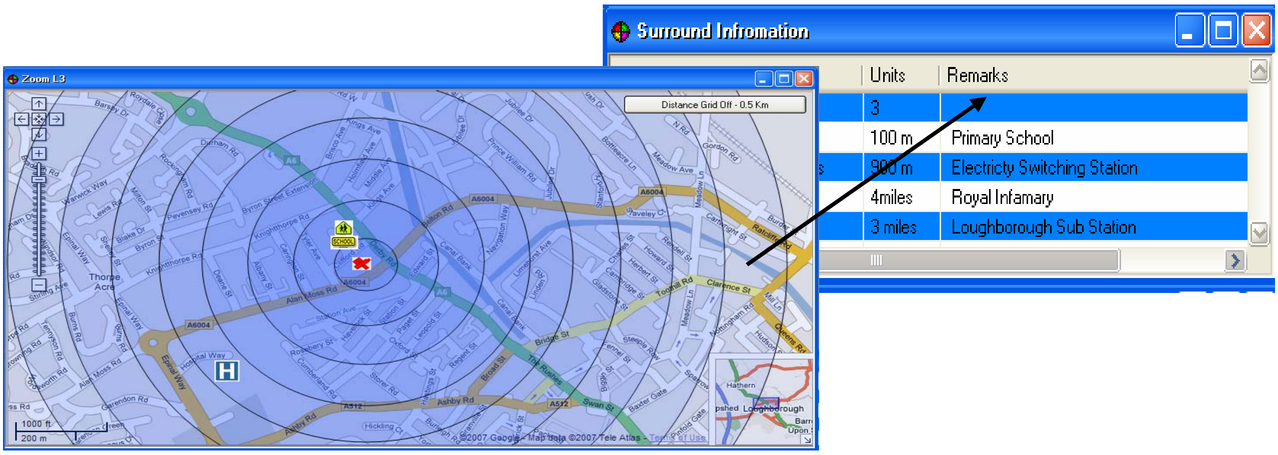
Figure3: Level 2 Information: Comprehension.



Interfaces to present Level 2 SA Information: Comprehension

The interface shown in the Figure 3 illustrates the comprehension of previously perceived information at the level 1 SA. This interface is capable of integrating static building layout information with graphically represented dynamic information such as temperature, smoke, carbon monoxide and flame to form a comprehensive picture of the incident. Using different shades of colors this interface illustrates the level of propagation of temperature, smoke, flame and carbon monoxide. Further by using appropriate Marks and Numbers this interface is capable of locating the hazmat and resource information. Therefore, rather than presenting information with letters and numbers as in level1, the dynamic information can be meaningfully integrated with static information using graphical presentations to improve the SA of the incident commanders. Further this interface is embedded with the drill down capability, where additional details on each element shown in the picture could be obtained by clicking on the respective area or icon. For example by clicking on the icon representing LPG gas, an incident commander may able to obtain the detail information such as quantity, storage details and other hazmat data.

Figure4: Level 2 Information: Comprehension.

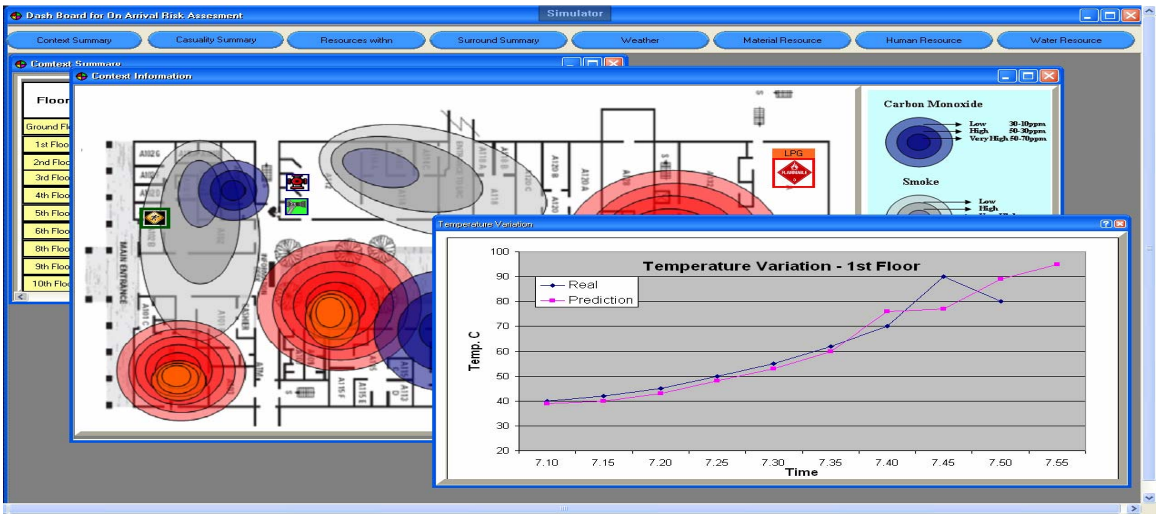


In addition to the above, Figure 4 represents an interface which is also capable of showing the comprehension of the previously perceived information at the level 1 SA. Specifically this interface shows the comprehension of the level 1 information corresponding to the Surround Information of an incident. By integrating this with graphical map data, it is capable of providing an overall picture of the incident surroundings. By graphically superimposing level1 information on to a map, it displays information on nearest: buildings, outside hazards, hospitals and police stations near to the vicinity of an incident. It also provides the location of the incident building with directions to its fire assembly points.

Interfaces to present Level 3 SA Information: Projection

With the level 3 information, the interface shown in the Figure. 5 provides a higher level of situation awareness to an incident commander to make accurate predictions on certain environmental parameters. This particular interface displays the variation of temperature over a period of time selected by the incident commander. It is capable of providing the actual and predicted temperature at equal time intervals. At the end of its time scale the graph shows the predicted temperature of the next time interval. This type of interface can provide valuable decision making support for incident commanders to help them make difficult predictions with confidence.

Figure 5: Level 3 Information: Projection



Conclusions and Future Work

As an initial step of fulfilling the limitations related to the onsite decision making support of front line fire fighters of the UK FRSs , this study explored the information requirements of selected core members in the UK firefighter hierarchy,. It then explored how to present and share information among fire fighter during the response phase of a fire. Previous information systems development efforts supporting fire emergency only addressed the information needs of different members in the fire fighter hierarchy in isolation. Therefore this particular study is unique as it has proposed a conceptual information system architecture recognizing the importance of sharing information among different members of first responder hierarchy. Further this study focused on combining real time contextual data with previously stored static scenarios to provide a higher level of situation awareness in the fire fighters. In addition, the software prototypes developed are significant as they are capable of displaying information requirements to the incident commanders to help carry out the initial risk assessment, which is considered to be one of the most cognitively demanding tasks during emergency response. Further these interfaces represent the functionality of an information system which is capable of supporting the decision making of fire fighters during the response phase of a fire emergency.

As the next phase of this study, the interfaces which have been already developed will undergo an iterative improvement process until they are capable of presenting the comprehensive dynamic information requirements of the end users. Parallel to such iteration, similar process will be adopted to develop the interfaces representing the job roles of Sector Commander, BA Commander and BA wearer. With the exploration of ideas and early feedback from the end users, these annotated prototypes will form the basis of specifications for the future implementation of the real-time software modules capable of looking after the information requirements of the first responders during the emergency response phase of a fire emergency.

Acknowledgment

This work is a part of the project of “Secure Ad-hoc Fire & Emergency Safety NETwork” (SafetyNET) funded by the Department of Trade and Industry (DTI) in the UK in 2006. The authors would like to express their appreciation to the DTI for the financial support and other industry partners for their corporation during this study.

References

BBC News 24 (2007). Four firefighters believed dead. http:// news.bbc.co.uk/ 1/hi/england/ Coventry Warwickshire/ 7076401.stm. (Last Accessed 20 February 2008)

Bretschneider, N., Brattke, S. and, Rein, K.(2006). Head mounted Displays for Fire-fighters. In Proceedings of the 3rd International Forum on Applied Wearable Computing, Bremen, Germany on March 15-16, 2006.

Computerized Equipment (2007). http://www.southwales-fire.gov.uk/ SWFSCMS/ WhatWeDo/control/equipment. (Last Accessed 20 April 2007)

Endsley, M. R., Bolte, B., & Jones, D. G. (2003). Designing for Situation Awareness: An Approach to Human-Centered Design. London: Taylor & Francis, London, UK.

Fire Service Manual - Volume 2 - Incident Command (1999). Crown Copyright 1999, UK.

Introduction to the Incident Command System (2007). http://www.wyfcda.f9.co.uk/ new/aboutUs/au_ics_chapter1.htm. (Last Accessed 20 April 2007)

Jiang, X., Chen Y.N., Hong, I.J., Wang, K., Takayama, A.L. and Landay A. J., 2004. Siren: Context-aware Computing for Firefighting. In the Proceedings of Pervasive 2004,April 18-23, 2004.

Prasanna, R.K.R, Yang, L.,King,M., 2007. Integrated Information Management System Model for Emergency Response. In the proceedings of the 13th International Conference on Automation and Computing, Stafford, England, Sep. 2007.

Riley, J. M., Endsley, M. R., Bolstad, C. A. and Cuevas, H. M., 2006. Collaborative Planning and SA in Army command and Control. Ergonomics, Vol. 49 No.12, pp.1139 – 1153.

The Overall Fire Picture – 2006 (2006). http:// www.usfa.dhs.gov/ statistics/quickstats/ index.shtm. (Accessed 20 April 2007)

Wilson J, Steingart,D., Romero,R., Reynolds, J., Mellers, E., Redfern, A., Lim, L.,Watts, W., Patton, C., Baker, J. and Wright, P. (2005). Design of Monocular Head-Mounted Displays for Increased Indoor Fire fighting Safety and Efficiency. Proceedings of SPIE , Bellingham, WA, 2005.

Yang, L. (2007). On-site Information Sharing for Emergency Response Management. Journal of Emergency Management, Vol5.No.5, pp55-64, Sep.-Oct.2007.

Yang, S.H. and Frederick, P. (2004). SafetyNET a Wireless Sensor Network for Fire Protection and Emergency Responses. Measurment+Control, Vol. 39, No.7, pp. 218-219.

Author Biography

Raj Prasanna is currently a PhD research student in the Business School of Loughborough University, UK. He received his MSc in IT degree from University of Colombo, Sri Lanka in 2005, MBA degree from the Postgraduate Institute of Management, University of Sri Jayewardenepura, Sri Lanka in 2000 and the BSc in Electronics and Telecommunications Degree from the University of Moratuwa, Sri Lanka in 1995. His research interests include management of information systems, human computer interface and information management for emergency response.

Dr Lili Yang is a lecturer in Information System in the Business School at Loughborough University, UK. She is a member of the British Computer Society (MBCS) and a Chartered IT Professional (CITP). Her research interests focus on information sharing and management for emergency services, security risk assessment, and wireless technologies in logistics. Her recent research has been supported by industries and research funding bodies such as the Derbyshire Fire and Rescue Services, BAE Systems, Engineering Physical Science Research Council (EPSRC), the Department of Trade and Industry (DTI), British Council, and the Royal Academy of Engineering.

Prof. Malcolm King is Professor of Management Sciences in the Business School at Loughborough University. As well as mathematical modeling, his research interests include the impact IT on all areas of management and the organizational and political aspects of systems development. He has also written on IT acceptance and is particularly interested in IT developments within small and medium enterprises. Recently, this work has concentrated on the alignment of IT within small firms and issues surrounding ecommerce. Several PhDs have been supervised in this area. Drawing together his modeling and IS expertise he has recently worked on the provision of information in emergency situations.