Proceedings of the Third International
Conference on Information (Info'2004)

ISBN 4-901329-02-2

Uncertain Information Processing Framework for Situation Awareness and Emergency Decision-Making

Jie Lu and Guangquan Zhang

Faculty of Information Technology,
University of Technology Sydney, PO Box 123, Broadway, NSW 2007, Australia
Email: {jielu, zhangg}@it.uts.edu.au

Abstract. Situation awareness (SA) has been considered as an important element to support emergency managers in finding ways to prepare suitable responses to crisis problems happen. Situation information processing technique is one of fundamental issues in the enhancement of SA analysis ability and development of high performance situation response systems. Various incompleteness and uncertainties are involved in situation information and its processing. This paper, as a preliminary study, identifies several uncertainty issues in situation information processing. This paper then presents a SA achievement and dynamic decision-making framework with a general architecture describing how to govern incomplete and uncertain situation information to derive awareness and support decision-making.
Key words: Situation awareness, Uncertain information processing, Emergency response systems

1. Introduction

Emergency management historically has focused on the immediate and urgent aspects of a disaster, response and post-disaster recovery. However, there is a growing awareness that emergency management should pay more attentions on finding ways to avoid crisis problems in the first place if possible and preparing suitable response to minimize the lose for those that undoubtedly will occur, such as fires, floods, epidemic even terrorism. It will play very important roles for any organizations or governments in any country. This mission requires technical support in effectively analysing a situation and deriving awareness information to emergency management officers for understanding the situation and making decisions. Situation awareness (SA) technique has been considered as an important element to do so.

Initially, the decision makers in emergency management lack a complete picture of the situation and replies upon the system for access to the missing information. Also, emergency management officers often only imprecisely or ambiguously know a situation and use uncertain (fuzzy) information to present it. SA information processing technique is one of fundamental issues in the development of high performance situation response information systems. Although a lot of research has been done in SA area existing SA technology cannot well handle the incompleteness and uncertainty of situation information and its processing. This paper identifies four issues of incompleteness and uncertainty involved in situation analysis and awareness deriving. It then builds a SA achievement and dynamic decision-making framework with a general architecture describing how to govern and fusion incomplete and uncertain situation information to derive awareness information, as individual or teams, and how to support dynamic decision-making.

2. Uncertain Issues in Situation Awareness and Emergency Decision-Making

SA is defined by Endsley [2] "as the perception of elements in the environment, the comprehension of their meaning in terms of task goals, and the projection of their status in the near future." The process of achieving SA is called situation analysis or situation assessment. Situation assessment is based on acquired situation information that can be implicit or explicit. Awareness information (SA information) is derived as results of situation assessment. The term SA is commonly used in the human-computer interaction community where the concerns are to design computer interfaces so that a human operator can achieve

SA in a timely fashion [1]. It is also used in the data fusion community where it is more commonly referred to as situation assessment [3]. SA has been largely studied as an important element in diverse military and pilot systems using observation, experiments and empirical methods. However, there are four problems that influence situation analysis and awareness deriving to be solved, in particular.

a) Situation information incompleteness: Initially, the decision makers in emergency management often lack a complete picture of the situation and replies upon the system for access to the missing information. Also, decision makers in emergency management may not either know what information may relate to the problem or may not consider all relevant information. Information missing will affect decision makers' correct understanding for a situation and finding a suitable solution for the problem. How to assess a situation based on amount of situation information available, and find a sufficient answer based on incomplete information is one of fundamental issues in the development of situation response systems.

b) Situation information uncertainty: Two basic elements are needed to support SA. The first is a representation of a situation. The second is approaches or tools for situation assessment [10]. There are a lot of uncertainty issues involving the two elements. It is natural that in a real-world people often only imprecisely or ambiguously know a situation and use uncertain (fuzzy) information to present it. Particularly, some explicit situation information cannot be expressed into precise information. Therefore SA has to be generated based on imprecise and inaccuracy information through suitable fuzzy information processing.

c) Team SA inconsistency: Controlling large dynamic systems, such as an emergency co-ordination among several large organizations, is beyond the competence of one single individual. Instead a team works cooperatively to coordinate and control the environment. The degree to which every team member possesses SA for task performance is team SA [6]. The level of overall SA across the team becomes an important issue, possibly leading to performance errors in team SA. An example of this can be found in the context of a building security control room in which several security personnel need to know certain pieces of information to safely and effectively complete a work process. If a person acting as a supervisor is aware of the critical information, but a person in direct control of the process is not, the SA of the team may be deficient and, consequently, performance and system safety may suffer. This is a SA inconsistency causing error. Team SA also involves uncertainty issue. Team members often use linguistic terms to communicate each other and to describe their identification and judgment for a situation in attempting to reach an optimal solution. In a sequence processing, relevant SA information is passed on to the next person that may produce fewer uncertain hypotheses. Parallel processing would make the team members developing different situation models that at the end might lead the team members to talk about different conceptions of the situation, which are ambiguous.

d) Uncertainty in the model of situation assessment and dynamic decision-making: The existing SA models can be classified as descriptive and prescriptive [10]. Descriptive models are suitable for capturing basic issues of decision-making. Numerous descriptive SA models have also been proposed for modelling military domain such as Endsley's model [2]. A few prescriptive models have been proposed such as McCarley's model [5]. Most of which use if-then production rules to assess a situation. Such models are easy to implement but lack the use of all information of the SA. Both kinds of models are not sufficient to support SA in emergency management. Very important, there have not been SA model addressing uncertainty issues. In fact, SA assessment elements involve with uncertainty and SA assessment measures also with uncertainty. Under these uncertainties, SA information derived will have uncertainty feature as well. An emergency decision will be thus made based on uncertain SA information, uncertain awareness relationships and uncertain alternative solutions. The main reason to have so much uncertainty is that SA systems are human-centred

systems rather than only computer software. Therefore, the roles of human and computer and the influence of uncertainty for SA must be described in SA frameworks or models.

3. A framework in SA achievement and emergency decision-making

SA has been recognized as an element to support emergency management and crisis problem finding. This requires the development of general SA analysis models and approaches. Although the elements of SA vary widely between domains, the nature of SA, as the output of a kind of information systems, and the mechanisms used for achieving SA can be described generically. Dynamic decision-making in emergency environment depends on the results of SA assessment. SA is aware of the environment based on the perception of what is happening or has the potential to happen. If a department or a command centre is to make the right decisions for a crisis problem, it must be able to assess the environment, the threats and the opportunities faced. The environment information come from various data sources, and cannot be captured precisely and completely. Also, people may not know what information will relate to a possible problem. Accepting as a given that the situation information is incomplete and uncertain, perception of SA can therefore only be obtained through processing the uncertain or incomplete information. Some researchers have pointed out the importance of team SA and noted that team SA has different requirements than individuals. Just adding independent SA of individuals is not enough, as team members share information with each other at all times via different representation media and verbal communication [6,7]. Teams rely heavily on a common overview of the situation so that team members share the workload [8]. Team SA is the sum of the SA for each individual, independent of any overlap in SA requirements among members. This is supported by the notion that if each of two team members needs to know a particular piece of information, it is not sufficient that one knows it perfectly but the other does not [4]. The level of SA to each team member for task performance may be different and uncertain. The performance of team SA assessment depends on effective team SA assessment techniques that involve information gathering from multiple timescales and team cooperation between timescales. The team SA is an overall awareness of how the situation looks and forms a hypothesis about how it might evolve by integrating all members' awareness, which involves uncertainty as well.

Based on above analysis three main sources of situation information in a SA environment: real world, system and team members, are identified. Incompleteness exists in all the three kinds of information. Based on Endsley [3]'s SA model and information processing theory [9], three levels of information processing to derive a SA are identified: Level 1 is perception of current situation information; Level 2 is comprehension of current situations; and Level 3 is projection of future status where the ability to forecast future situation events allows for timely decision-making. Fig.1 shows the proposed framework of SA achievement and dynamic decision-making. In this framework SA as a stage separate from decision-making and performance. The main reason is that it is entirely possible to have perfect SA but make an incorrect decision. Uncertain information processing is involved at all the three levels and decision-making. First, representation of uncertain information appears at level 1 as situation information obtained is often described precisely. Information missing is also an issue to be handled at the level. The comprehension of information meaning level involves uncertain information filtering and integration. SA as a construct also encompasses how people combine, interpret, store and retain uncertain information. Team members may have different ways to know their environment and have different accurate degrees to acquire situation awareness and with different confidence. Therefore, SA at the level includes not only perceiving information, but also the integration of multiple pieces of information and determination of their relevance to the team's goals. There are uncertainty problems at the level 3 as well. The projection will be completed based on uncertain information and imprecise criteria or rules of reasoning.

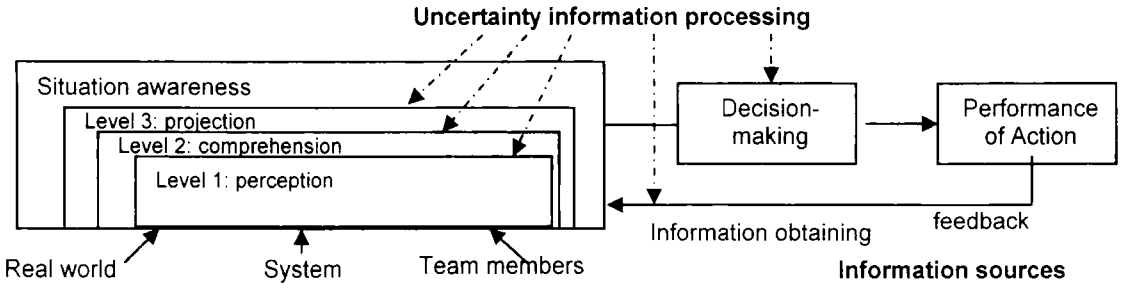


Fig. 1. Uncertain information process requirement in SA achievement and dynamic decision-making

A set of uncertain information processing issues are involved in the framework in order to derive SA, including uncertain information representing, judgment, integrating and forecasting for SA. a) Uncertain information representation: A representation of a situation needs information about relevant objects, their features and logical actions; b) Uncertain information judgment: This involves to correctly identify relevant information and to find association relationships among the information; c) Uncertain information fusion (integration): People often know something is occurring or that a particular piece of information exists, but they do not understand how it relates to the overall situation. Information fusion is the process of combining information collected from various disparate sources to refine state estimates and predictions; d) Uncertain information prediction (forecasting): This will address identification and characterization of status in the near future, based on the results of uncertain information judgment and fusion.

4. Further study

The study will attempt on how incomplete and uncertain situation information is represented and processed, and how awareness information is derived and perceived based on situation information. Related techniques to filtering, fusion and forecasting uncertain situation information will be developed.

References

[1] Artman H. (2000). Team situation assessment and information distribution, *Ergonomics*, Vol. 43, No 8,1111-1128

[2] Endsley M. R. (1995), Toward a theory of situation awareness in dynamic systems, *Human Factors*, Vol. 37,No.1 32-64.

[3] Endsley M.R and Garland, D. (2000), Situation Awareness Analysis *and Measurement*, Lawrence Erlbaum, Associates, Publishers, Mahway, New Jersey, 2000.

[4] Endsley M. R, and Jones W. M. (1997), Situation awareness, information warfare & information dominance, *Endsley Consulting, Belmont, MA, Tech. Rep.* 97-01

[5] McCarley J. S., Wickens C.D., Goh J. and Horrey W.J. (2002), A computational model of attention/situation awareness, *The 46th annual meeting of the human factors and ergonomics society*, Human Factors and Ergonomics Society.

[6] Salas E., Prince, C., Baker, D. P. and Shrestha, L. (1995), Situation awareness in team performance: implications for measurements and training, *Human Factors*, Vol.37, 123-136.

[7] Schwartz D. (1990), *Training for Situation Awareness*. Houston, TX: Flight Safety International.

[8] Sebok A. (2000), Team performance in process control: influences of interface design and staffing levels, *Ergonomics*. Vol. 43, No 8, 1210-1236.

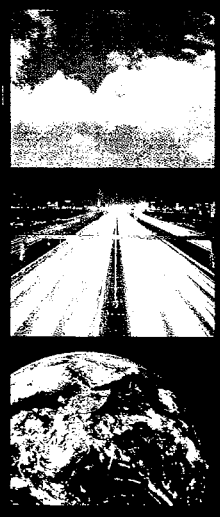
[9] Wickens C. D. (1992), *Engineering Psychology and Human Performance*, 4th edn (New York: Harper Collins).

[10] Zhang W. and Hill R. (2000), A template-based and pattern-driven approach to situation awareness and assessment in virtual humans, *The fourth international conference on Autonomous agents*, Spain, ACM Press New York, USA, 116-123.

ISBN 4-901329-02-2

Information

Proceedings of the Third International Conference on



November 29 - December 2, 2004,
Hosei University, Tokyo, Japan

Edited by
Lei Li
Kang K. Yen

Published by International Information Institute
www.information-iii.org