Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-19 (2016) 537–542

# Analysis of Team Situation Awareness Using Serious Game and Constructive Model-Based Simulation

**Tetsuo Sawaragi*, Kohei Fujii*, Yukio Horiguchi* and Hiroaki Nakanishi***

** Department of Mechanical Engineering and Science, Kyoto University, Kyoto, Japan.*

*(Tel : +81-75-383-3581; e-mail: sawaragi@me.kyoto-u.ac.jp)*

*Abstract*: In this study, analysis of team situation awareness using a serious game of supply chain management for steel production is provided. By tracing the development of the performances of the game made by two different teams, a comparative analysis is done with respect to team situation awareness shared within the team. Especially, we focus into the individual players' mental models that may evolve and grow as they accumulate a number of game sessions. From the acquired protocols of players during the sessions, players' temporal mental models of situation awareness are traced, then the progress of team situation awareness among the players are derived. Through a comparative analysis of the two different teams with respect to their shared team situation awareness, we discuss about the relationships between the maturity of the teams and performance scores attained by the teams. Finally, a simulation model for generating such multiple players' behaviors within a variety of teams is proposed. This is based upon a descriptive decision model of Garbage Can Model, and findings discovered during the gaming sessions are verified and generalized through a model-based constructive approach.



*Keywords:* Team situation awareness, collaboration, serious game, cognitive task analysis, supply chain management, garbage can model.

## 1. INTRODUCTION

The development and research on *situation awareness* made huge advances in the applied cognitive psychology and human factors field (Endsley, 1995). A simplified definition of situation awareness (SA) is to know what is happening around oneself in a complex environment, in order to take an optimal decision, and is an accepted concept of cognition in complex, socio-technical and dynamic environments. Though the original idea of SA concerned with the individual decision makers, it has been extended to an idea of team situation awareness (team SA) (Hackerman, 1987; Salas et al., 1995). This is because operators often need to collaborate and situation awareness should be extended beyond the individual to a team or group level. Team SA is defined as "*the degree to which every team member possesses the SA required for his or her responsibilities*" (Endsley, 1995, p. 39). The success or failure of a team depends on the success or failure of each of its team members.

Current industries are forced to act according to the rapid changes of circumstances such as market changes and to the change of economic environments. Moreover, the reduction of expert workers may bring about drop of the work quality, and the occurrences of malfunctions caused by aging of equipment may bring about a variety of unexpected fluctuations frequently during the production. Taking measures suited to those occasions is realized through the human-system co-creative safety management for establishing resilience against a variety of disturbances. This situation is also true and becoming serious in the steel production industries. Steel production consists of a complex supply chain, where multiple decision makers in each process of works should collaborate to attain higher productivity as well as to recover from the unexpected disturbances. Wherein, systematical approaches to establishing resilient production and operation systems are needed, and we introduce a means of serious games for supply chain management for this purpose.

Various games have been developed so far, and especially a category of serious games is a set of simulations of real-world events or processes designed for the purpose of solving a problem. One of the well-known serious game is developed for the Dutch railway infrastructure organization PRORAIL, to test new process innovations with the railway operational chain (Lo et al., 2014). In Japan, the Iron and Steel Institute of Japan (ISIJ) started an academia-industries collaborative project from 2012 to 2015 on the topic of human-system co-creative risk management for establishing resilience against the disturbances. Within this project, Mizuyama's group has developed a serious game named COLPMAN (COLLABORATIVE PRODUCTION MANAGEMENT), which is a virtual supply chain of a large-scale make-to-order company through making production and delivery decisions (Nonaka et al., 2016). The general purpose of this game is twofold; to use games as a platform for policy development, such as the introduction of new management concepts for attaining the resilient and coordinated production scheduling by multiple actors consisting of the supply chain, and secondly as a research tool to test hypotheses on human behaviors within the supply chain management system.

In this paper, we use this testbed of COLPMAN game to analyze team situation awareness developed during a series


Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.617

of game sessions performed by a couple of teams, each of which consists of multiple players. Based on the analysis of players' decisions and interaction behaviours, some key issues for team situation awareness are identified, and then a novel constructive approach to replaying behaviours of the players are introduced. That is, a simulation model for generating such multiple players' behaviours within a variety of teams is proposed. This is based upon a descriptive decision model of Garbage Can Model (Cohen et al., 1972), and findings discovered during the empirical analysis of gaming sessions are verified and generalized through a model-based constructive approach.

## 2. OVERVIEW OF THE GAME

COLPMAN is a serious game of supply chain management for steel production. Players of the game consists of the five players; a *headquarter* accepting orders from customers, an *upstream factory* producing materials, and three *downstream factories* processing materials into products that are to be delivered to the customers. This game operates a virtual supply chain of a large-scale make-to-order company through making production and delivery decisions. Details of the game are provided in Nonaka et al. (2016) of this session.

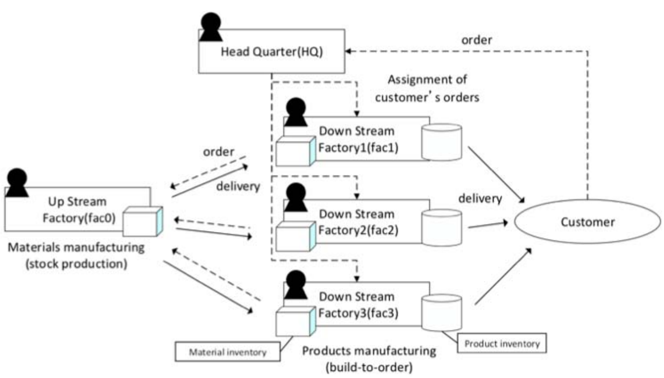


Fig.1 The flow chart of the COLPMAN game

Figure 1 illustrates flows of goods and information among the players. Game starts when headquarter accepts orders from customers. An order is defined as a triple consisting of customer, type (of five types), and size (of five sizes) of goods to order. Customers are assumed to be located in places with different distances from downstream factories which supply products to the customers, i.e., times needed to deliver products to customers are different due to a distance gap. Then, headquarter makes a rough plan by assigning downstream factories to produce ordered goods as well as determining appointed dates of delivery of each order. Each of assigned downstream factories makes its own schedule of producing the assigned products as well as making orders of the materials needed for that production to an upstream factory. Orders from the downstream factories to the upstream factory are specified as a tuple of quantity and types of material. Then, accepting orders from downstream factories upstream factory makes its schedule to produce materials to be supplied to the downstream factories. Both of upstream and downstream factories have some amounts of stocks of materials and products, respectively, and should manage these not to produce excess stocks. When the schedules are fixed, productions in each factory start and materials produced in a upstream factory are delivered to down stream factories, while downstream factories continue their productions using the supplied materials producing the final products delivered to customers. Wherein, a variety of costs are defined; costs for stocks, costs for delivery, costs for set-up change, and penalties for late delivery. Five players should collaborate to make their decisions on making production schedules and ordering by communicating with each other to maximize sales volumes and minimizing costs and penalties. The game platform consists of decision-making sessions and a simulating part that simulates productions in factories and flows of goods resulted by the former decisions. In the simulation part, a variety of fluctuations such as the ones of lead times, occurrences of manufacturing defects and arrivals of express orders are embedded stochastically. Therefore, each player has to carefully adjust and modify their ongoing plans by communicating the other players in necessity.

The game session consists of a series of trials, where each trial is composed of four *terms* and each term is divided into four *periods*. At the beginning period of each term, regular orders from customers come to headquarter and all five players start scheduling the production by making material orders in discussing each other, and when they are fixed they are sent to the simulating part that simulate production and deliveries period by period. Because of accidental occurrences of fluctuations, each player has to adjust their decisions at the beginning of the subsequent period in monitoring the production status.

## 3. COGNITIVE TASK ANALYSIS OF THE GAME

Despite the large volume of researches on situation awareness across domains, there proposed numerous definitions of SA. One of the most accepted definitions of situation awareness is that of Endsley (Endsley, 1995), called three-level model. Endsley extended a single person's SA into team SA, where teams are recognized as unit of analysis and team SA is more than a simple sum of individual SA. Related to this, Endsley also defined shared situation awareness as "*the degree to which team members possess the same SA on shared SA requirements*" (Endsley & Jones, 1997). There are information requirements that are relevant to multiple team members, and a major part of teamwork involves the area where these SA requirements overlap.

During COLPMAN game sessions performed by five human players, each player has a subgoal pertinent to his/her specific role that feeds into the overall team goal. Associated with each member's subgoal a set of SA elements about which he/she is concerned exists. As the members of a team are essentially interdependent in meeting the overall team goal, some overlap between each member's subgoal and their SA requirements will be present. To measure and visualize team SA acquired during the game sessions, we introduce a function hierarchy for the game, in which a set of SA elements to be shared with others are structurally configured with different abstraction levels to analyze the shared