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An intelligent algorithm for performance evaluation of job stress and HSE factors in petrochemical plants with noise and uncertainty

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ABSTRACT

This study presents an intelligent algorithm based on Adaptive Neuro-Fuzzy Inference System (ANFIS) and statistical methods for measuring job stress in noisy and complex petrochemical plants. Job stress is evaluated against health, safety, environment and ergonomics (HSEE) program in the integrated algorithm. The algorithm is composed of seventeen distinct steps. To achieve the objectives of this study, standard questionnaires with respect to HSEE are completed by operators. The average results for each category of HSEE are used as inputs and job stress is used as output for the algorithm. Moreover, operators' stress level with respect to HSEE is evaluated by the algorithm. Finally, operators with weak stress level are identified. The advantage and superiority of the intelligent algorithm are shown by error analysis in contrast with conventional regression approaches. This is the first study that introduces an integrated intelligent algorithm for assessment and improvement of job stress and HSEE in noisy, complex and uncertain environment.

1. Introduction

HSE programs attempt to decrease workplace injuries, health issues and severe effects to environment. Also, effective application of ergonomics factors in workplace could create a balance between human operators and job design. This in turn could increase human productivity, safe workplace and job satisfaction. The principal of HSE is now well recognized in most petrochemical plants. Several industries use the term HSE to describe health, safety and environment as one entity (Deng, 1999). Various studies have shown positive influences of applying ergonomics rules to the workplace including machine, job and environmental design (Abou-Ali & Khamis, 2003; Ayoub, 1990a, 1990b; Azadeh, Mohammad Fam, Khoshnoud, & Nikafrouz, 2008; Blanchard & Fabrychy, 1998; Shikdar & Das, 2003; Shikdar & Sawaqed, 2004). Studies in ergonomics have created data and instructions for industrial applications (Blanning, 1984; Bryden & Hudson, 2005; Burri & Helander, 1991). However, there is still a low level of acceptance and few applications in industry. Lack of utilization of the ergonomics rules could bring inefficiency to the workplace. Moreover, ergonomically deficient workplaces could cause physical and emotional stress, low productivity and poor quality of working conditions (Azadeh, Mohammad Fam, Khoshnoud, et al., 2008; Burri & Helander, 1991; Cabrero-Canosa et al., 2003; Caldwell, Breton, & Holburn, 1998). The ergonomics deficiencies are main cause of health hazards in workplaces and decreased workers' productivity (Champoux & Brun, 2003). However, ergonomics applications have not achieved significant momentum in developing countries (Azadeh, Mohammad Fam, Khoshnoud, et al., 2008).

By considering health, safety, environment and ergonomics (HSEE) encourages organizations to adopt a healthy and safe life-style. It insists on ecological efficiency by continuously improving energy consumption and decreasing waste. It optimizes the relation between human operators, machines and work environment (Azadeh, Mohammad Fam, Khoshnoud, et al., 2008; Changchit & Holsapple, 2001; Chen & Yang, 2004). It also provides considerable benefits by decreasing the costs associated with workplace accidents and injuries.

There have been several studies on the impact of HSE and Ergonomics issues in manufacturing systems. Saksvik and Nytr

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(1996) presented an implementation of internal control (IC) of health, environment and safety (HES) in Norwegian enterprises. IC involves systematic actions that reduce stress and occupational ill-health which will, in turn, prevent injuries and workplace absenteeism (Saksvik & Nytr, 1996). Eklund (1997) presented the relationships between ergonomics and several factors such as work conditions, product design, ISO 9000, continuous improvements and TQM (Eklund, 1997). Azadeh, Nouri, and Mohammad Fam (2005) evaluated the impact of total system design factors (TSD) on human performance in a power plant (Azadeh et al., 2005). In addition Azadeh, Keramati, Mohammad Fam, and Jamshidnejad (2006) described an integrated macroergonomics model for operation and maintenance of power plant (Azadeh et al., 2006). Torp and Moen (2006) presented the effects of implementing or improving occupational health and safety management system. They considered management on the work environment, occupational health and safety behavior and musculoskeletal health of workers in small and medium-sized companies (Torp & Moen, 2006). Mohammad Fam, Azadeh, and Azam Azadeh (2007) used non-parametric statistical analysis to investigate the impacts of total ergonomics factors on local factors (Mohammad Fam et al., 2007). Azadeh, Mohammad Fam, Sadjadi, and Hamidi (2008) presented an integrated framework for designing and development of the integrated health, safety and environment (HSE) model in a gas refinery in Iran. It was shown that total ergonomics model is superior to the conventional ergonomics approach (Azadeh, Mohammad Fam, Sadjadi, et al., 2008). Moreover, Azadeh, Mohammad Fam, and Nouri (2008) present a framework for development of integrated intelligent human engineering environment in complex critical systems. By integration of conventional Health, safety and environment (HSE) with job systems, health, safety, environment and ergonomics (HSEE) is developed. In fact, re-engineering organizational structures and teamwork through electronic data interchange are considered in their study (Azadeh, Mohammad Fam, & Nouri, 2008). Duijm, Fiévez, écileGerbec, Hauptmanns, and Konstandinidou (2008) showed that HSE management would benefit greatly from guidance on how to use existing management systems efficiently and also from the further development of meaningful safety performance indicators that identify the conditions prior to accidents and incidents (Duijm et al., 2008). Mohammad Fam, Azadeh, Faridan, and Mahjoub (2008) used behavior sampling (SBS) technique to evaluate the workers safety behavior in an Iranian gas treatment company (Mohammad Fam et al., 2008). Again, Azadeh, Mohammad Fam, and Azadeh (2009) implemented a study on a gas treatment company to show the need for and superiority of HSEE over conventional HSE and by responding to a questionnaire ergonomics in addition to HSE are evaluated in this refinery. HSEE integrated the structure of human and organizational systems with a conventional HSE system and it is caused enhancing reliability, availability, maintainability and safety through the proposed integrated framework (Azadeh et al., 2009). Hivik, Moen, Mearns, and Haukelid (2009) reported a qualitative interview study of 31 employees, with and without leadership responsibility, employed in a Norwegian petroleum company to gain insight into how the workers conceptualized the HSE concept, different aspects of HSE culture and differences between the informants (Hivik et al., 2009). Hassim and Hurme (2010) presented an Inherent Occupational Health Index has been developed for assessing the health risks of process routes during process research and development stage. The method takes into account both the hazard from the chemicals present and the potential for the exposure of workers to the chemicals (Hassim & Hurme, 2010). Besides, the certification and implementation of occupational health and safety management systems have become a priority for many organizations. To investigate the status of implementing occupational health and safety management systems (OHSMSs), and to explore important performance indicators for OHSMSs' performance appraisal in the printed circuit board (PCB) industry in Taiwan, Chen, Wu, Chuang, and Mac (2009) administered a survey to eleven PCB manufacturers, all of which have been certified as compliant to the guidelines on OHSMS of the Occupational Health and Safety Assessment Series (OHSAS) 18001, and twenty six OHSAS specialists from the academe. Chang and Liang (2009) developed a model to evaluate the performance of process safety management systems of paint manufacturing facilities. The model was constructed based on a three level multi-attribute value model (MAVT) approach. Einarsson and Brynjarsson (2008) suggested an approach for a human factor program as a learning experience through case studies from incidents and accidents in Iceland and Netherlands. From these observations, a more holistic system view is proposed involving authorities and contractors. Azadeh et al. (2011) presented an adaptive neural network algorithm for assessment and improvement of job satisfaction with respect to HSE and ergonomics program in a gas refinery. However, the stated study is not capable of handling noise and uncertainty associated with large and complex systems such as petrochemical plants. The present study however presents a robust algorithm to cover noise and uncertainty associated with job stress and HSE factors in petrochemical plants.

1.1. Job stress

Workplace stress is the harmful physical and emotional response that occurs when there is a poor match between job demands and the capabilities, resources, or needs of the workers. Job stress results from the interaction of the worker and the conditions of work. "Views differ on the importance of worker characteristics versus working conditions as the primary cause of job stress (Niosh, 1999)". The differing viewpoints suggest different ways to prevent stress at work. According to one school of thought, differences in individual characteristics such as personality and coping skills are very important in predicting whether certain job conditions will result in stress. In other words, what is stressful for one person may not be a problem for someone else. This viewpoint underlies prevention strategies that focus on workers and ways to help them cope with demanding job conditions. Sauter, Murphy, and Hurrell (1990) introduced the means to change the organization to prevent job stress through workload balance, job design, work definition, participative management, work schedule, etc.

There are several studies about stress in literature. There are many behavioral disturbances in modern man as well as psychosomatic disturbances such as stress. In a highly competitive job market, where the means of work and information are rapidly transformed, one of the stress factors is the professional insecurity. There are also other factors linked to the organization of modern production such as: the space factor and the psycho-social and inter-subjective relations of the working environment. The modern organization of work produces stressing conditions which may develop psychosomatic disturbances in the productive agents. Although the professionals feel capable of acting in some places of work, the fast transformations in modern world create some insecurity which provokes anxiety leading to stress. Due to this process, the cognitive ergonomics is formally integrated to the productive system; integrating to the business charts and assuming a technical feature to the extent that it has helped in the transformation of knowledge into production force, so as to measure the work for the man (Moiseichyk, De Campos, & Bento, 2000).

The nature and feasibility of preventive measures taken to reduce work stress in the construction industry are discussed by