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A neuro-fuzzy algorithm for assessment of health, safety, environment and ergonomics in a large petrochemical plant

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ABSTRACT

Process plants such as petrochemical units have been continuously trying to improve Health, Safety, Environment and Ergonomics (HSEE) programs. This study proposes an adaptive network-based fuzzy inference system (ANFIS) for assessment of HSEE programs in a petrochemical plant. The proposed neuro-fuzzy approach is applied to a set of operators in the petrochemical unit to show its applicability and superiority. 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 accomplishment of HSEE programs is used as output for the algorithm. Moreover, this algorithm is used to rank operators performance with respect to HSEE. Finally, the algorithm identifies efficient operators with respect to HSEE. This is the first study that introduces an intelligence algorithm for assessment and improvement of HSEE program in a petrochemical plant.

1. Significance

Accomplishment of HSEE programs is a crucial procedure for managers because this will lead to providing a safe and healthful working environment for all workers as well as the general public. Performance assessments of operators with respect to HSEE are fundamental to management planning and control activities, and accordingly, have received considerable attention by both management practitioners and theorists. This study proposes a neuro-fuzzy algorithm for measuring and improving HSEE programs. The proposed algorithm of this study is flexible and identifies the preferred estimation model based on the results of ANFIS and MAPE (Minimum Absolute Percentage Error). Moreover, superiority of the flexible intelligent algorithm has also been shown in contrast to conventional regression approaches.

2. 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 worker productivity and create improved worker safety (physical and mental). The principal of HSE is now well recognized. Several companies use the acronym HSE to describe health, safety and environment as one entity (Deng, 1999). Various studies have shown positive influences of applying ergonomic rules to the workplace including machine, job and environmental design (Azadeh et al., 2008a; Abou-Ali and Khamis, 2003; Shikdar and Sawaqed, 2004; Ayoub, 1990a, 1990b; Blanchard and Fabrychy, 1998). Studies in ergonomics have also produced data and instructions for industrial applications (Blanning, 1984; Bryden and Hudson, 2005; Burri and Helander, 1991). However, there is still a low level of acceptance and few applications in industry. The main concern of work system design in context of ergonomics is improvement of machines and tools. Lack of utilization of the ergonomic rules could bring inefficiency to the workplace. Besides; an ergonomically deficient workplace can cause physical and

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emotional stress, low productivity and poor quality of work conditions (Azadeh et al., 2008a; Burri and Helander, 1991; Cabrero-Canosa et al., 2003; Caldwell et al., 1998). It is believed that ergonomic defects in industry are main cause of health hazards in workplaces, low levels of safety and decreased workers' productivity (Champoux and Brun, 2003). Although ergonomics applications have achieved significant momentum in developed countries, knowledge remains low in developing countries (Azadeh et al., 2008a).

By considering health, safety, environment and ergonomics (HSEE), health and safety have the first priority among other factors. It encourages employees to adopt a healthy and safe life-style. It contributes to eco efficiency by continuously improving energy consumption and decreasing waste. It designs and develops products to have the minimum contrary influence on the environment throughout their life-cycle. It optimizes the relation between operator and machine in a manner that operator faces the least weariness and has the most efficiency (Azadeh et al., 2008a; Changchit and Holsapple, 2001; Chen and Yang, 2004).

The main objective of present work is to propose a Neuro-Fuzzy algorithm for measuring and improving accomplishment of HSEE among operators. In fact in the present study, accomplishment of HSEE has been reviewed and its efficiency has been analyzed and forecasted. By using Normal probability plot inefficient operators are recognized based on failing to address accomplishment of HSEE. In the next section the review on the current literature has been done. Main concept and utilized techniques have also explained in the Section 3. In the Section 4 an adaptive intelligent algorithm has been presented. The detailed results of applying proposed Neuro Fuzzy algorithm have been explained in Section 5 based on actual petrochemical plant data.

3. Literature review

In this study application of neural networks and fuzzy systems in efficiency analysis is discussed. Within the efficiency literature, few applications have been made in this field and most of them use neural networks. For instance consider DEA approach, a basic principle to use ANNs is for generalizing efficiency frontier functions which concavity is an important characteristic of them and they may be applied to frontier analysis (Wang, 2003). Moreover, the efficiency prediction power of ANNs is unique and the flexibility of it to solve complex problems, where the main information lies implicitly in the data, is very applicable (Wu et al., 2006).

The idea of combination of neural networks and DEA for classification and/or prediction was first introduced by Athnassopoulos and Curram (Athanassopoulos and Curram, 1996). They treated DEA as a preprocessing methodology to screen training cases in a study. Their application is bank with multi-output: 4 inputs, 3 outputs. Costa and Markellos (1997) analyzed the London underground efficiency with time series data for 1970–1994 where there are 2 inputs – fleet and workers – and 1 output – kms (Costa and Markellos, 1997). They explain how the ANN results are similar to COLS and DEA. They proposed two procedures: a) similar way to COLS after neural training; b) by an oversized network until some signal to noise ratio is reached. Then, inefficiency is determined as observation-frontier distance. However, ANN offers advantages in the decision making, the impact of constant versus variable returns to scale or congestion areas (Costa and Markellos, 1997). Santin and Valino (2000) study on education efficiency by a two-level model: student–production function is estimated by ANN–and school (Santin, Valin, 2000; Pendharkar, Rodger, 2003). They infer that ANN is superior to econometric approach at frontier estimation.

Commonly, neural network technique is used as a complementary tool for parametric and non-parametric methods such as DEA, to fit production functions and measure efficiency under non-linear contexts. In fact, applying ANN can reduce the restrictive assumptions each of these methods. Whereas Neuro-Fuzzy is combination of ANN and fuzzy system, have a benefit of two models and is selected instead of ANN (Buragohain and Mahanta, 2008). Hybrid neuro-fuzzy approach has been used for the generation of measuring points for knowledge-based inspection planning. Also, it has been used for control of complex manufacturing systems. Some of the neuro-fuzzy systems are well-known by their short names. For example, ANFIS, DENFIS, SANFIS and FLEXNFIS, etc. (Jang, 1993; Kasabov, 2002; Wang, Lee, 2002; Rutkowski, Cpalka, 2003). ANFIS is used in present study as one of algorithm tools.

4. Basic concepts and techniques

Basic concept and techniques that has been utilized in the proposed algorithm will be discussed in the next sub sections.

4.1. HSEE

Health, safety and environment (HSE) was introduced first as the important management approach in 1985 by the chemical industry (Stephan, 2007). Actually it was a reaction to catastrophic accident. There are also close relationship between health, safety, environment and ergonomics factors. Basically, ergonomics is concerned with all those factors that can affect people and their behavior (Azadeh et al., 2008a). Azadeh et al. have introduced HSEE for the first time that consider ergonomic in its management approach view ( ). Inappropriate design between man and machine could cause to decreased safety. Inappropriate design of system causes to management error. Management error and work environment harmful factors could cause human error. HSEE has defined human factors and ergonomics as the environmental, organizational and job factors, human and individual characteristics which influence behavior at work. Exact consideration of human factors improves health and safety by reducing the number of injures and cases of ill-health at work. It also provides considerable benefits by decreasing the costs associated with such accidents and enhancing efficiency.

There have been several studied on the impact of HSE and Ergonomics issues in manufacturing systems. Saksvik et al. (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. Eklund (1997) presented the relationships between ergonomics and several factors such as work conditions, product design, ISO 9000, continuous improvements and TQM. Azadeh et al. (2005) evaluated the impact of total system design factors (TSD) on human performance in a power plant. In addition Azadeh et al. (2006) described an integrated macro ergonomics model for operation and maintenance of power plant. 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. Moreover, Azadeh et al. (2008c) presents 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. Mohammad Fam et al. (2008) used behavior sampling (SBS)