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Fire probability prediction of offshore platform based on Dynamic Bayesian Network

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ABSTRACT

By integrating Markov model with Bayesian Network, an improved Dynamic Bayesian Network (DBN) model is proposed in this paper. It could be used to predict the dynamic probability of offshore platform fire. It is a new stochastic model which could process dynamic data. Three innovations are achieved in building this model. Firstly, a modified Human Factor Analysis and Classification System (HFACS) model is used to provide guidance for the construction of BN in describing the sequence of causes for offshore platform fire. Secondly, the prior probability is determined by using Evidence Theory model based on historical data. Thirdly, the conditional probability table of basic events is calculated by integrating Fuzzy Analytic Hierarchy Process (AHP) with Hierarchical Node Distance Formula. Lastly, the transition probability of BN is obtained based on Markov model. There are three major functions of the new model. First of all, through forward reasoning, the dynamic probabilities of platform fire at different time are obtained. Second, based on the diagnosis reasoning, the impact of human and organizational factors on the fire is researched. Last, the sensitivity analysis and uncertainty analysis of human, organizational and equipment factors are also researched to identify the significant causes and to quantify the effect.

1. Introduction

Hydrocarbon fires of offshore platform are extremely hazardous for health, safety and the surrounding environment (Paik and Czujko, 2011). According to the statistics of HSE, more than 70% of the accidents that occur on offshore platform stem from hydrocarbon release and fires (HSE, 2005). Therefore, it is crucial to do quantitative risk assessment (QRA) of offshore production in order to identify the safety measures needed to prevent hydrocarbon release and fire accidents (Wang et al., 2011a,b). Several works have been done to carry out QRA of offshore platform (Abimbola et al., 2014; Khakzad et al., 2013; Jin and Beom-Seon, 2015; Chu et al., 2017). A method (called BORA-Release) is presented to carry out QRA on the platform specific hydrocarbon release frequency (Aven et al., 2006.). A case study is demonstrated on offshore oil and gas production platform with the purpose to test the above BORA-Release model (Sklet et al., 2006). Tamim et al. discusses the approaches of different organizations on leading indicators characterization in the drilling industry for predicting kick, which is a major precursor to blowouts and hydrocarbon release (Tamim et al., 2017). Early kick detection and blowout control decision-making methods for managed pressure drilling automation are proposed to ensure the delivery of safer wells with lower non-productive time (Vajargah and Oort, 2015). The occurrence of a kick and associated blowout risk are researched to prevent the disastrous fire and explosion accidents (Nayeem et al., 2016). More and more scholars have been shifting their focuses to the fire and explosion risk on offshore platform because of the increasing frequency and damages of fire and explosion accidents (Jin et al., 2016). EFEF JIP project (Suardin et al., 2009; Paik et al., 2010; Kim et al., 2010) assessed the risk of hydrocarbon fire and explosion in offshore installations. Bow-Tie is combined with Bayesian Network (BN) model to assess the risk during drilling operation (Khakzad et al., 2013; Abimbola M., 2014).

However, there is a limitation in the traditional QRAs which usually do not consider the effect of Human Organizational Factors (HOF) (Wang et al., 2011a,b). A coherent approach to explore BN in developing better risk models for complex social-technical systems is proposed to consider the influences of HOFs (Trucco et al., 2008). Dynamic BN method is used to perform predictive and diagnostic analysis in different time slices for risk assessment of lost circulation during three drilling scenarios (Wu et al., 2016). BN has been widely used for dealing with uncertain information and risk analysis (Cai et al., 2014, 2017a, 2017b; Barua et al., 2016; Yeo et al., 2016; John et al., 2016; Liang et al., 2017). But BN

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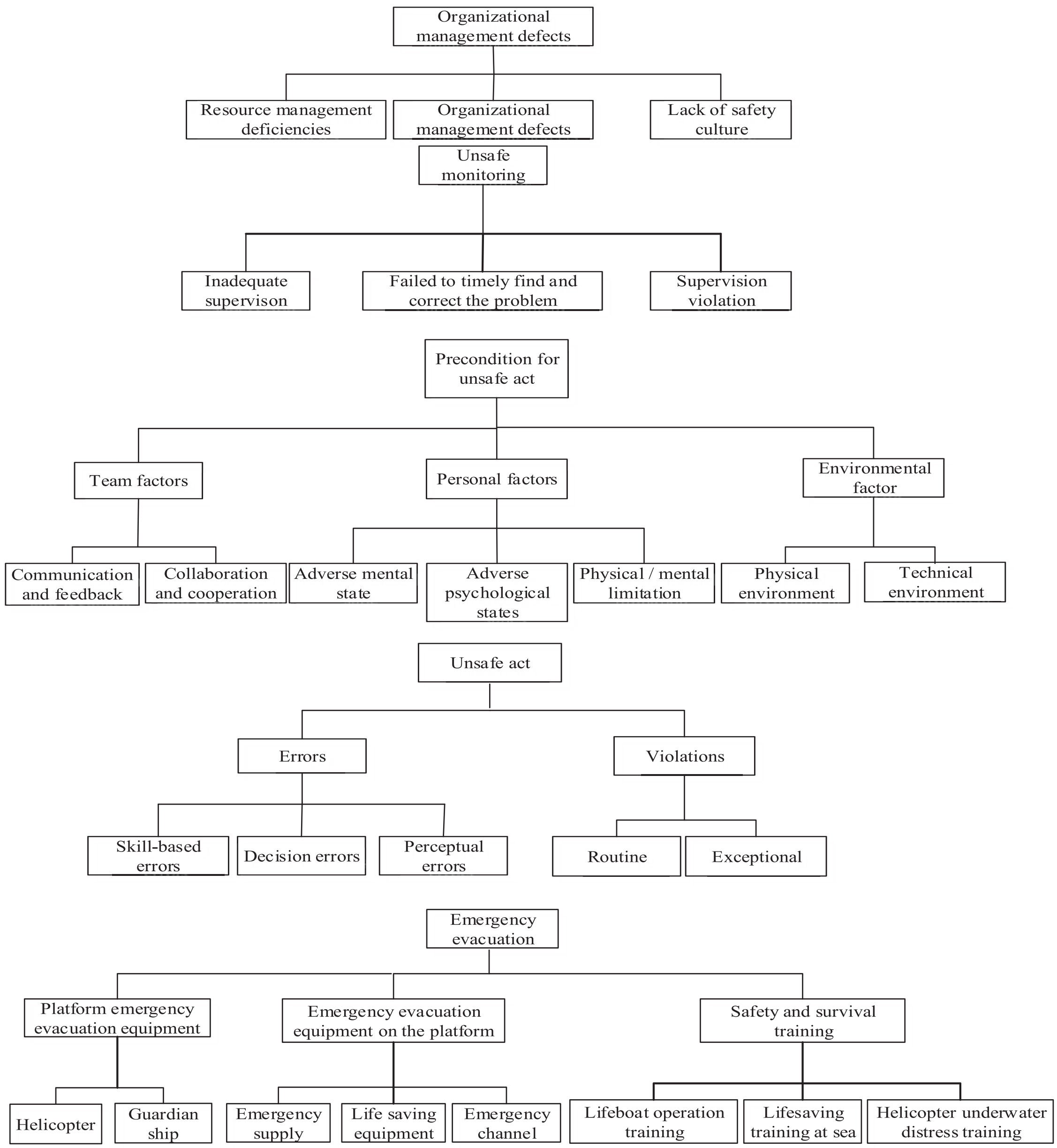

Fig. 1. The modified HFACS framework.

model cannot incorporate unobserved variables easily because the size of the internal conditional probability table (CPT) for a child node can quickly become quite large. With regards to the elicitation of CPT for HOFs in BN, it is worthwhile to note that reliable HOF data are usually absent (M. Grabowski et al., 2009). In such situations, CPT can be elicited using judgments from experts. However, experts may find it difficult to come up with precise probability values for the relationships among nodes (Chen H.H. et al., 2007). Fuzzy AHP can tackle fuzziness and uncertainty of vague decision-making more efficiently using fuzzy sets, membership functions, and fuzzy numbers (Lee S.K. et al., 2008). So, in this paper, the conditional probability table of BN is calculated by integrating Fuzzy Analytic Hierarchy Process (AHP) with Hierarchical Node Distance Formula. A DBN model is proposed to predict the dynamic probability of offshore platform fire by integrating BN with Markov model.

The rest of the paper is organized as follows: In Section 2, the DBN model and all the relevant algorithms are described. In section 3, the case of oil and gas processing unit is demonstrated to predict the probability of offshore platform fire. Uncertainty analysis and sensitivity analysis are carried out to determine the main contributors to fire accidents and how they affect the offshore fire probability. In section 4, conclusions and results are presented.

2. Dynamic Bayesian Network model

2.1. Modified Human Factor Analysis and Classification System

Identifying the sequence of causes is a very complex task in accident analysis. It is especially so when the accidents are caused by human error. In order to establish a human error analysis framework, a Human Factor Analysis and Classification System (HFACS) is proposed based on the dominant and implicit errors of the Reason model (Wiegmann and Shappell, 2012). The HFACS can be used to classify and analyze human factors associated with accidents and incidents, which is divided into four levels:

1) Unsafe acts
2) Preconditions for Unsafe acts