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Alarm management based on diagnosis

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Abstract: The transitions between operational modes (startup/shutdown) in chemical processes generate alarm floods and cause critical alarm saturation. We propose in this paper an approach of alarm management based on a diagnosis process. This diagnosis step relies on situation recognition to provide to the operators relevant information on the failures inducing the alarms flows. The situation recognition is based on chronicle recognition where we propose to use the hybrid causal model of the system and the expertise to generate the pattern event sequences from which the chronicles will be extracted using the Heuristic Chronicle Discovery Algorithm Modified $HCDAM$. An illustrative example in the field of petrochemical plants is presented in the article.

Keywords: Alarm management, Diagnosis, Chronicles, Transitional stages, Hybrid models

1. INTRODUCTION

The petrochemical industries losses have been estimated at 20 billion dollars only in the U.S. each year, and the AEM (Abnormal Events Management) has been classified as a problem that needs to be solved. Hence the alarm management is one of the aspects of great interest in the safety planning for the different plants. In the process state transitions such as startup and shutdown stages, the alarm flood increases and generates critical conditions in which the operator does not respond efficiently. A dynamic alarm management is then required (Beebe et al. (2013)). Currently, many fault detection and diagnosis techniques for multimode processes have been proposed; however, these techniques cannot indicate fundamental faults in the basic alarm system, Zhu et al. (2014); in the other hand the technical report Advance Alarm System Requirements EPRI (The Electric Power Research Institute) suggests a cause-consequence and event-based processing. Therefore, in this paper, a dynamic alarm management strategy is proposed in order to deal with alarm floods happening during transitions of chemical processes. This approach relies on situations recognition (i.e. chronicle recognition). As, the efficiency of alarm management approaches depends on the operator expertise and process knowledge, our final objective is to develop a diagnosis approach as a decision tool for operators. The paper is divided into 5 sections. Section 2 presents the Chronicle based alarm management proposal. The Section 3 presents the case study related with an illustrative application in the petrochemical sector. Section 4 expresses the formal framework for this analysis including the hybrid causal model and the description of the chronicle discovery algorithm. Finally, the construction of the chronicle database is given in the section 5.

2. CHRONICLE BASED ALARM MANAGEMENT

The Chronicle Based Alarm Management (CBAM) methodology proposed in this paper merges different techniques to take the hybrid aspect and the standard operational procedures of the concerned processes into account. These two features stand out of the literature (Jing et al. (2013), S. Xu (2014), Srinivasan et al. (2005), Bhagwat et al. (2003)). Another important aspect is the analysis of the Dynamic Alarm Management: most of the time the alarm is assumed to be a static indicator, in our proposal an alarm is an event with an occurrence date and the alarm flow is formally modeled by a chronicle (Vasquez et al. (2015)) as presented in section 4.2. The position of our approach with respect to other approaches stands in that we use information about the procedural actions related to the continuous variables behavior in a formal diagnosis process. The main steps of this methodology are:

(1) From the standard operating procedures and from the evolution of the continuous variables, determine the set of event types in startup and shutdown stages.
(2) From the expertise and the event abstractions determine the date of occurrence of each event type to construct the representative event sequences.

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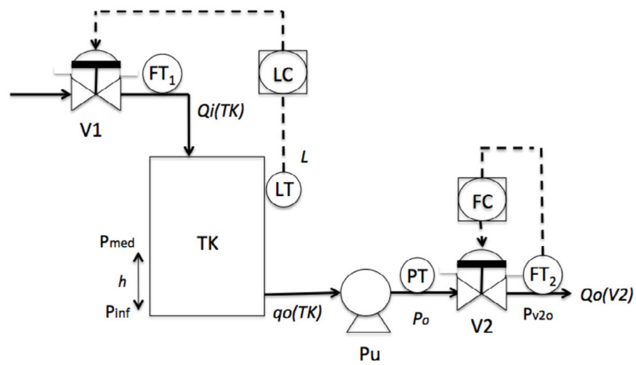

Fig. 1. Hydrostatic Tank Gauging

(3) From the representative event sequences in each scenario, determine the chronicle database using the algorithm $HCDAM$ (Heuristic Chronicle Discovery Algorithm Modified).

In a general way, the chronicle learning requires a lot of representative event sequences of each scenario. In our case no historical information related to startup or shutdown stages is available, as these types of scenarios do not occur frequently. Therefore, it is by simulation that the representative event sequences of each scenario are obtained. The different steps of the methodology will be detailed further in the article and the next section presents the case study.

3. CASE STUDY - HTG (HYDROSTATIC TANK GAUGING) SYSTEM

The Cartagena Refinery in Colombia as recently be enriched by news units and elements. Our proposal aims at helping the operator to recognize dangerous conditions during the startup stage of the refinery with modified equipments. To start our analyze, we focus on the startup and shutdown stages in the unit of water injection. This process is a HTG (Hydrostatic Tank Gauging) system composed of passive components, active components and sensors. The passive components are components which cannot change the operational state, e.g. the tank (TK). In the other hand, the active components can change their states of operation by a procedural action, e.g. the two normally closed valves ($V1$ and $V2$) and the pump (Pu). The sensors, correspond to the instrumentation that measures the continuous variables, e.g. level sensor (LT), pressure sensor (PT), inflow sensor (FT_1) and outflow sensor (FT_2), see Fig. 1. The standard operating procedures give us the standard procedural actions for the startup and shutdown stages. For the correct execution of these procedures, the operators must execute the actions according to the correct evolution of the procedure. The abnormal situations are detected when the evolution of the procedural actions and the continuous variables evolution do not correspond to the standard operating procedure and wrong event type occurrences, happen. The fluctuations of the inlet flow of the tank, the response time of the pump that causes the outlet pressure and other conditions generate uncertain that can be determined by expertise. because to obtain a complex model which simulate all the process uncertain requires a lot of time and resources to build it.

4. FORMAL FRAMEWORK

This section presents the formal framework of the Chronicle Based Alarm Management (CBAM) methodology proposed.

4.1 Hybrid Causal Model

The hybrid system is represented by an extended transition system, whose discrete states represent the different modes of operation for which the continuous dynamics are characterized by a qualitative domain. Formally, a hybrid causal system is defined as a tuple Pons et al. (2015):

$$\Gamma = (\vartheta, D, Tr, E, CSD, Init, COMP, DMC) \quad (1)$$

Where

- $\vartheta = \{v_i\}$ is a set of continuous *process variables* which are function of time t.
- D is a set of discrete variables. $D = Q \cup K \cup V_Q$.
  - · Q is a set of states q_i of the transition system which represent the system operation modes.
  - · The set of auxiliary discrete variables $K = \{K_i, i = 1, ...n_c\}$ represents the system configuration in each mode q_i, where K_i indicates the discrete state of the active components.
  - · V_Q is a set of qualitative variables whose values are obtained from the behavior of each continuous variable v_i.
- $E = \Sigma \cup \Sigma^c$ is a finite set of observable (Σ_o) and unobservable (Σ_{uo}) event types, noted σ, where:
  - · Σ is the set of event type associated to the procedural actions in the startup or shutdown stages.
  - · Σ^c is the set of event type associated to the behavior of the continuous process variables.
- $Tr : Q \times \Sigma \rightarrow Q$ is the transition function. The transition from mode q_i to mode q_j with associated event σ is noted (q_i, σ, q_j).
- $CSD \supseteq \bigcup_i CSD_i$ is the *Causal System Description* or the causal model used to represent the constraints underlying the continuous dynamics of the hybrid system.

  Every CSD_i associated to a mode q_i, is given by a graph $(G_c = \vartheta \cup K, I)$. I is the set of influences where there is an edge $e(v_i, v_j) \in I$ from $v_i \in \vartheta$ to $v_j \in \vartheta$ if the variable v_i influences variable v_j. A dynamic continuous model DMC_{I_K} is associated to every influence $I_k \in I$, see Fig. 2. The model of the active component corresponds to a transfer function of first order with delay. The set of components is noted as $COMP$.
- $Init$ is the initial condition of the hybrid system,

4.2 Chronicle model

Let us consider time as a linearly ordered discrete set of instants. The occurrence of different events in time represents the system dynamics and a model can be determined to diagnose the correct evolution. An event is defined as a pair (e_i, t_i), where $e_i \in E$ is an event