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Data-driven Artificial System of Parallel Emergency Management for Petrochemical Plant*

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Abstract **- A data-driven system of parallel emergency management is designed to manage production safety emergencies caused by natural or human-induced disasters in the petrochemical plant, combining with the parallel management theory based on ACP (Artificial Systems, Computational Experiment, and Parallel Execution) approach. Data is acquired by use of techniques including video monitoring and detection, which is the premise of building Artificial System. Based on mass data of the key state variables, Artificial System is designed by using fuzzy expert system and other intelligent modeling algorithms. Finally, the parallel emergency solution is provided for emergency management in one case of ethylene plant, and it can make a great improvement to the emergency management of the plant.**

Index Terms - Parallel Emergency management, ACP, Data-driven

I. Introduction

With the rapid development of the petrochemical industry in China, the petrochemical enterprises are growing in the comprehensive, systematic, complicated direction. However, factors such as growing scope, increasing staff and changing climate are put more and more the petrochemical enterprises at the risk of suffering to the natural and human-induced disasters. Recent tragic events are the fires in July 16, 2011 and in August 29, 2011, in Dalian Petrochemical Company, and the explosion in January 7, 2010, in Lanzhou Petrochemical Company. Another example is the plugging and explosion of oil pipeline accident in November 13, 2005, in Jilin petrochemical company, which caused the water contamination of the Songhua River, even lead to social security and diplomatic issues. Those disasters remind us that the lives and property are so vulnerable to the impact of the adverse disasters. Therefore, the emergency management is a key issue of growing importance in the current globalized world.

Emergency management is the management of handling and avoiding disaster, involving disaster preparation, disaster response, material support and social reconstruction in natural or human-induced disasters [1,2]. Research on emergency management mainly focuses on natural disasters, human-induced disasters and engineering system disasters. In recent years, as sudden incidents have greatly increased, emergency management becomes a hot point of research [3-8]. Fan WC proposed the advisement and suggestion to scientific problems of emergency management for public incidents [1]. Lv HY and others did study on statistical analysis and prediction of production safety accident in China [4]. Liu YM and others put forward the complex mechanism of sudden accident in large scale projects [5].

In this paper, a data-driven parallel system of emergency management is designed, combining with the parallel management theory based on ACP approach (Artificial System, Computational Experiment, and Parallel Execution), which is a methodology of complex system. In this system, the mass of data are acquired by detecting techniques, and then stored into a large database of historical disaster instances to create Artificial System of the emergency management.

The remainder of this paper is organized as follows: the problem addressed and its importance in petrochemical plant is discussed in Section 2. Artificial System of parallel

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emergency management is described in Section3. Section4 gives a conclusion.

II. PARALLEL EMERGENCY MANAGEMENT

At present, the petrochemical plant invested a certain amount of funds in the emergency management to avoid the risks of accidents caused by the natural or human-induced disasters. However, due to the characteristic of petrochemical production enterprises, such as the production process with high temperature and high pressure or low pressure, flammable and explosive materials, many risk source and hidden dangers exist in it and its emergency management is still facing at a huge challenge.

Now, HSE (Health, Safety, and Environment) emergency management is adopted in petrochemical production enterprises. In this method, each organization is required to do the risk analysis, so that the possible risks and dangers of their own activities can be predicted in advance. Therefore, the effective measures can be taken to prevent and control the accident, so as to reduce the probable casualties, property loss, and environmental pollution. It is a kind of modern management mode, which emphasizes prevention and continuous improvement, with a high degree of self-discipline, self-perfection, and incentive mechanism.

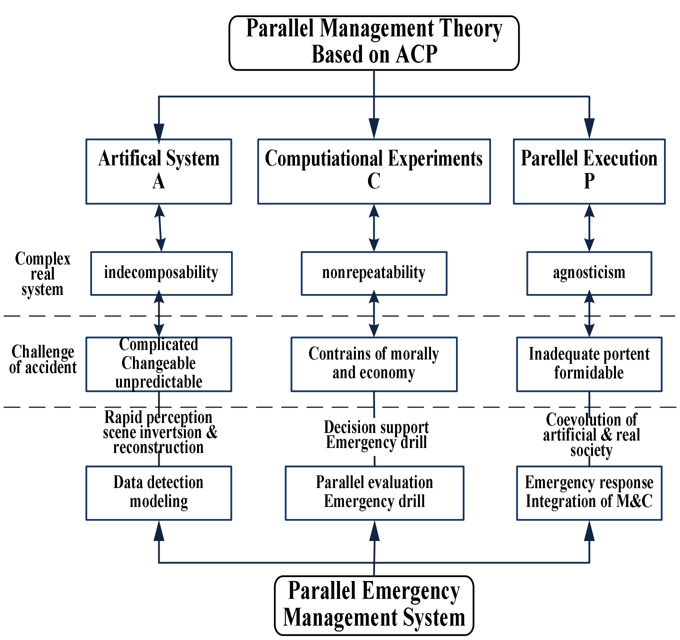

Fig.1. Parallel management theory based on ACP approach

For the open complex giant system, Parallel management systems theory and ACP approach are first proposed [9-12] by Professor Fei-Yue Wang, world famous researcher, which can be constituted of three parts including Artificial System, Computational Experiments and Parallel Execution, as shown in Figure 1. The group headed by Professor Wang applied the ACP approach to emergency response of the unconventional incidents, and will develop the comprehensive solution and the relative key technologies, in Institute of Automation, Chinese Academy of Sciences.

ACP approach is proposed for the purpose of modeling, analysis, and control of the complex systems[12].Basically, it consists of three steps:1) building the modeling of the complex system, as Artificial System ;2)based on the artificial system, analysis and evalution of the control strategy of the complex system, wich is so called Computational Experment; 3) control and management the real world and the artificial through the interaction mechanism, wich is called Parellel Execution.

In this paper, the goal is building the artificial system of emergency management in petrochemical plant, wich one part of the parallel emergency management system, belonging to Artificial System in ACP approach.

III. A DATA-DRIVEN ARTIFICIAL SYSTEM

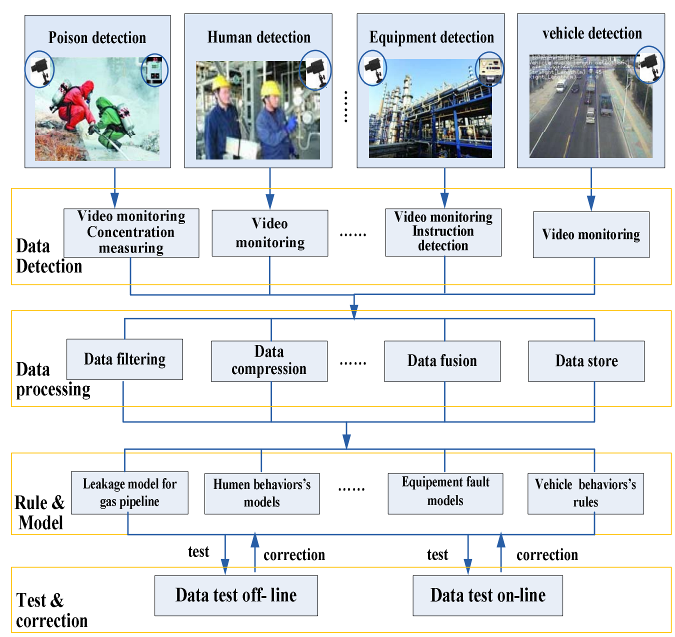

Fig.2. Diagram of building the artificial system

As the petrochemical enterprises are growing rapidly and continually, its emergencies Management is tending towards complication, networking, and socialization. For the significant characteristics of emergency such as sufficient, the complexity and social, a data driven management solution of parallel emergency response is proposed, combining with theory with ACP approach. This solution consists of three parts: Artificial System, Computation Experimentation, and Parallel Execution. Artificial System is constructed by the data detection and data-driven algorithms, which is the virtualization and digitalization of the actual system mapping to the cyberspace. Based on Artificial System, the computational experiment can execute to compute the output of the system under the given the input, and find the optimal state under the constrained conditions. Then, based the results of the computational experiment, Parallel Execution can carry out the interaction between the artificial system and the actual system.

Therefore, Artificial System is the essential part in the parallel system. The key point of the paper is constructing the artificial system of emergency management for the petrochemical plant. The methodology of building the artificial system is shown in the Figure 2.

To create the artificial system of the petrochemical plant, the important models of subsystems are constructed by the use of the data detection, such as the leakage models for gas pipeline, the human behavior's models, the equipment fault models, and so on. Base on the subsystem's models, the model of data-based rules is created for the decision support, which is essentially expert system.

A. Data detection

In the emergency response and disposal, the timely, rapid, accurate detection plays an important role. For strengthening the perceptive function, three key techniques are adopted. First, the video monitoring technique is used to keep watch on the important equipments, workers in key posters, and the environments in dangerous areas. Second, the instrumentations are applied to measure the essential denotative parameters, e.g. the density of inflammable, explosive, hazardous gases in the environment, the pressure of overhead tank, and so on. Third, the social sensing network is introduced to observe and analyze the staff mention before, during, after the emergency. The data detection techniques are shown in figure 3.

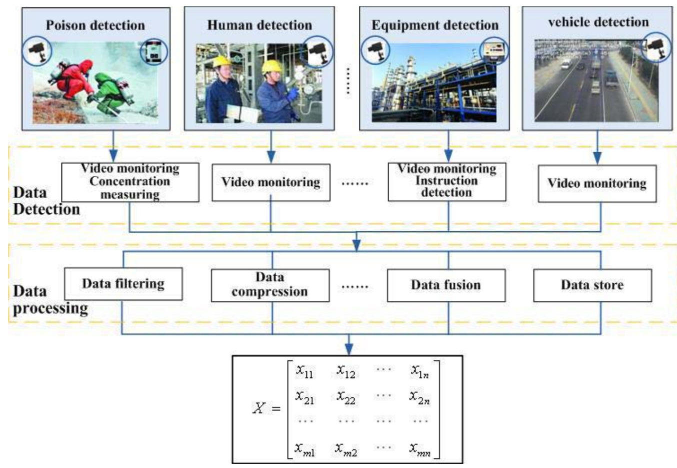

Fig. 3. Diagram of data detection and processing

Based on the detection techniques, the basic raw data used in the system are considered as a database, and can be viewed as a real-valued matrix $X=(x_{ab})_{mn}$, in m instances and n variables $X_1,...,X_n$. One instance means a historical accident scenario and each variable is an important parameter in order to describe the accident.

B. Knowledge representation

Then, the basic raw data is categorized base on the fuzzy method. Each variable X_i is partitioned into a set of classes $A_{i1},A_{i2},...,A_{ic}$ in sort ascending, as shown in table 1. Each class is categorized by the historical experience and data. The membership function u is a trapezoidal function. $u(x_i,A_{ij})$ means the probability of x_i belonging to the class A_{ij}, as follow:

$$u(x_i,A_{ij})=\begin{cases} k_1(x_i-\varepsilon_1),\varepsilon_1\le x_i<\varepsilon_1+\Delta \\ k_1\Delta,\varepsilon_1+\Delta\le x_i<\varepsilon_2 \\ -k_1(x_i-\varepsilon_2)+k_1\Delta,\varepsilon_2\le x_i<\varepsilon_2+\Delta \end{cases} \quad (1)$$

Where, k_1 is the slope of the hypotenuse; $\varepsilon_1<\varepsilon_1+\Delta<\varepsilon_2<\varepsilon_2+\Delta$, which are the boundary constants.

In this way, the historical information can be extracted by the knowledge representation. And according to the knowledge, the data-based rules can be constituted.

Table.1. an example of the classes of variable X_i

Class Number	Representation	Description
1	A_{i1}	the smallest
2	A_{i2}	smaller
3	A_{i3}	small
4	A_{i4}	small, but tending to middle
5	A_{i5}	middle
6	A_{i6}	big, but tending to middle
7	A_{i7}	big
8	A_{i8}	bigger
9	A_{i9}	the biggest

C. Data-based rule

If the phenomenon is $X_1,...,X_n$ in the m instances, the consequences are described as $Y=\{y_1,y_2,...,y_p\}$ in p variables. Then, combining with the historical data, the knowledge rule can be concluded as followings:

R: if X_1 is A_1 and X_2 is A_2 … X_n is A_n, then Y is B

Where A_1, A_2 … A_n are the classes of X_1, X_2 … X_n; B is can certain value of Y consequences variables. In this way, the knowledge database can be constituted. And for facing with a new emergency j, the consequences variable can be obtained:

$$Y^j=(y_1^j,y_2^j,...y_p^j)=Y_1u(X_1^j)+Y_2u(X_2^j)+Y_mu(X_m^j)$$

Where Y_1, Y_2,… Y_m are the historical data in m instances; $u(X_i^j)$ is the membership function of the $\{x_{j1},x_{j2},...,x_{jn}\}$ belonging to the historical data $X_i=\{x_{i1},x_{i2},...x_{im}\}$.

Therefore, the data-based rules can extract the knowledge from the historical data. Combining with the other models, e.g. leakage model of pipeline, hymen's behavior model, and so on, the data-driven artificial system of emergency parallel management for petrochemical Plant can be constituted.

D Fire emergency case

Based on the above approach, one example of fire emergency is given happened in large scale oil tank in one ethylene plant. First, the qualitative data described the fire should be achieved as Table.2.

Table.2. the fire description

Variables	Event decription	Key part & equipement	Large scale store facilities	Boiler& pressure evessel	Oil pipeline	Vehicle	Inflammable explosive hazardous chemicals
x_1	event class	√	√	√			√
x_2	materiel kind & quantity	√	√	√			√
x_3	primary cause	√	√	√			√
x_4	Fire scale & scope	√	√	√			√
x_5	equipement damage degree	√	√	√			√
x_6	6.circumjacent Building damage degree	√	√	√			√
x_7	property loss	√	√	√			√
x_8	leakage scope	√	√	√			√
x_9	casualties	√	√	√			√

The quantitative data $X=(x_1,x_2,...,x_9)$ should be computed by fuzzy method. According to the quantitative analysis, the solution can be obtained.

Suppose that the fire happens in large scale oil tank, which is the key part & equipment, large scale store facility, pressure vessel and storing the inflammable explosive hazardous chemicals. The solution of emergency is as follows:

Table.3. the solution of fire emergency in the oil tank

Step	Measure	Description
1	Separation & evacuation	Prohibit the irrelative person and vehicle from entrancing; fire-fighting forces is reasonably stationed
2	Saving the casualties	Send the casualties to hospitals; organize the doctor and secure a medical adequate supply
3	Organizing fire-fighting	According to the wind direction and the character of oil tank, organizing reasonable fire fighting
4	Avoid the oil leakage and diffusion	To stop the fire spreading, avoid the oil leakage and diffusion.
5	Stop the secondary disaster	For the nearby oil tanks, make the measures of cooling, pressure-releasing, and others
6	Support the adequate fire-fighting supply	Support the adequate the water, foam concentrate, and other material.
7	Measures when out of control	Evacuate the scene and neighboring residents, and assist local government to deal with the fire.

IV. CONCLUSIONS

A data-driven artificial system of emergency management is designed, combining with the parallel management theory based on ACP approach. Based historical mass data of key state variables, data-driven modeling algorithms, such as fuzzy expert system, are applied to build the artificial system. Based on the artificial system, computational experiment and parallel execution can be realized to optimize and evaluate the production safety emergency management solution of complex systems. Therefore, the data-driven artificial system supports the solution of actualizing the modeling of parallel emergency system.

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