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ACP based 3D Emergency Drills System for Petrochemical Plants

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Abstract – To further enhance emergency management skills of an organisation's emergency response personnel, emergency response training,especially 3D emergency drill, is currently becoming more and more important in the petrochemical sector. So, a novel 3D emergency drills system is designed and developed based on ACP approach, which can be used for mocking emergency response plan drills and evaluating the plan. A case study reveals that the performance of the system is good and the system can meet the needs of emergency response training and optimizing emergency response plan in petrochemical plants.

Index term – ACP Approach, Artificial Systems, Computational Experiments, Parallel Execution, Mock-Drill, Emergency Response Training

Ⅰ. INTRODUCTION

In petrochemical industry, there are many hazardous (toxic, flammable, and explosive) and high-energy installations. They can potentially cause major accidents endangering the economic loss, casualties and environmental pollution. Although risk is inevitable, the adverse effects of accidents can be mitigated through an effective emergency response. The loss for an organization with a strong emergency response system can be reduced to 6% of the loss for the same organization with poor emergency system[1].emergency response plan as part of the emergency response system is a guide document to insure the rapid, orderly and effective rescue in the emergency response to major accident or disaster[2].

However, simply drafting a response plan that prepares for naturally, accidentally, or intentionally caused disaster or emergency scenarios is not enough. Companies must be prepared to budget for and secure the necessary resources to make this happen, provide an appropriate administrative structure to effectively manage the accident, and practice, practice, practice. Training and maintenance of the plan is critical to ensure that all concerned understand who makes decisions, how the decisions are implemented, and the roles and responsibilities of participants. Personnel involved in managing a crisis must be assigned their roles and be able to respond immediately and effectively.

So emergency response training is currently receiving increasing emphasis in petrochemical plants. Training for emergency response plan tends to take the form of exercises or drills. At present, three main types of exercise exist, namely, seminar, tabletop and live exercise in most petrochemical plants. Seminar and tabletop play an important role in clearing emergency response responsibilities of participants and emergency response process, but these two types of exercise cannot enhance trainee's ability to conduct decision making, coordination and communication in stressful situation involving information overload and a significant level of uncertainty due to the lack of exercise in real-world risk environment.

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At the same time, the traditional live exercise has the disadvantage of affecting production, dangerous, a great deal of manpower, material and financial resources consumption, inefficient and lacks of repetition. So, a novel 3D emergency response drills system was designed and developed based on ACP approch.

This paper is organized as follows: section Ⅱ describes the theoretical basis and general idea of the system research and development(R&D); section Ⅲ presents the architecture of the system and the development process; a case study is given on section Ⅳ of this paper. Finally, conclusions are drawn and prospects are presented in section Ⅴ.

Ⅱ.ACP APPROACH AND FRAMEWORK

2.1 ACP approach

There are as yet no effective, widely accepted methods for complex system issues due to the dynamics, uncertainty, and multiplicity of it. The ACP(Artificial Systems, Computational Experiments, Parallel Execution,ACP) approach was initially proposed for simulation, analysis, and control of complex systems based on the latest achievements of intelligence sciences by the professor fei-yue Wang in 2004[3,4,5,6]. Basically, the core step of the ACP approach is described as follow: firstly, artificial systems are built based on real-world systems; secondly, according to the actual needs, computational experiments are designed, and then the law and dynamic evolution mechanism of real-world are emerged by the mean of computational experiments in platform of artificial systems; finally, the better methods for solving complex system issues are obtained and the performance of corresponding real system is improved by the mean of parallel execution of real and artificial.

The approach is widely applied to solve complex system issues in many industries, such as petrochemical industry, traffic field, and information security field. Some remarkable progresses in the petrochemical industry were made, such as the extension of security operation cycle of production installation, the increase of production management efficiencies and the improvement of the emergency management level [7, 8, 9, 10].

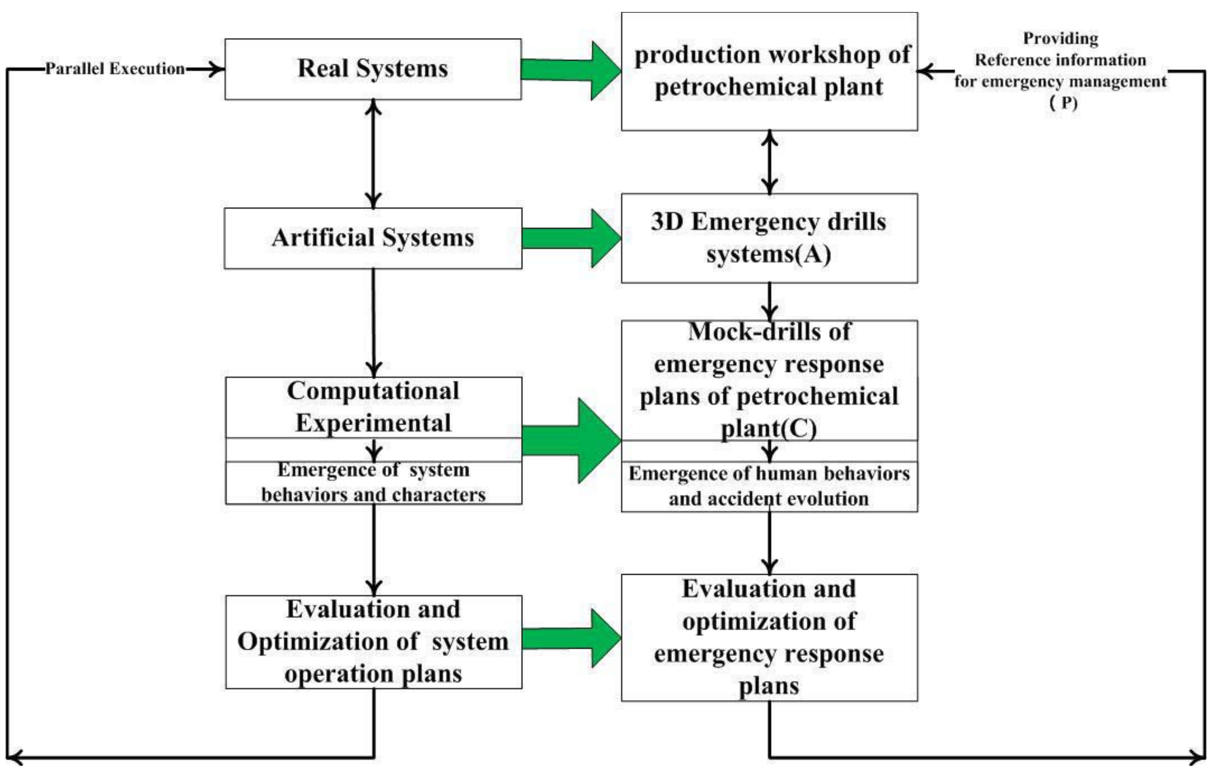

Fig1.Framework of 3D emergency drills system

2.2 The framework of 3D emergency drills system

Figure 1 describe the framework of 3D emergency drills system. In the left, the core of ACP approach is presented, while in the right, the corresponding framework of 3D virtual emergency drills system was described. The R&D process of system mainly include three steps as follow: firstly, building a 3D emergency drills system (a 3D production workshop) of petrochemical plant based on the real chemical workshop; secondly, implementing emergency response plan drills through this 3D platform, so human behaviors in emergency situation and accident evolution will be emerged; and finally optimizing the emergency response plans of the plant based on the result of the emergency drills and the analysis of potential risk, and then the better emergency response plans will be applied to emergency management in actual production. The above whole process has been executing cyclically to raise the emergency management level of petrochemical plants. This work will lay a solid technology foundation for achieving the goals of accident prevention, early elimination of the coming risk and early control of the event in petrochemical plants

III. ARCHITECTURE OF THE 3D EMERGENCY DRILLS SYSTEM

According to the framework of 3D emergency drills systems in Fig1, the architecture of the system was proposed in combination with the needs of petrochemical plants in Fig2. Further, in Fig3, a 3D emergency drills system was developed for ethylene cracking workshop of the SINOPEN Qilu branch olefin plant. The system development process is as follows:

[1] artificial systems： The artificial systems of 3D emergency drills systems are composed of three parts:

1) Database system, this system includes 3D scene module of production installation in cracking workshop (production area, ethylene control center, storage tank area etc) ;the hazard module (the model of ethylene leakage); the module of post roles(inspection operator, chief operator, monitor, operator for alerting on site, operator for evacuation on site, operator for guiding fire engine, operator for handling the accident etc); tools module(air breathing apparatus, ropes for alerting, combustible gas monitor, etc).

2) 3D engine, this part is the core of the system. it runs the system and monitors the whole system. All kinds of scene are displayed in a full 3D perspective by this engine. And further the function of the system, such as logic processing between different module, communication, human-computer interaction, and evaluation etc, are implemented through this 3D engine.

3) The interface of human-computer interaction. Through the interface of human-computer interaction, employees of the plant can mock emergency response plan drills, emergency response plans for potential risk can be revised and optimized.

[2] Implementation of the computational experimental

This process can be divided into three parts: 1) to design emergency response plans for potential risk based on hazardous analysis; 2) to implement computational experiments and evaluate the effectiveness of emergency response plans through the artificial systems; 3) to revise and optimize emergency response plans. For the purpose of keeping emergency response personnel's emergency response capacity, the whole process is doing dynamically.

[3] Parallel execution

The better emergency response plan is provided to the real-world production system by this function of the system. This function is implemented by the communication technology and database technology. An expert database of emergency response plans optimized by computational experiments for emergency personnel in petrochemical plant will be built. So in emergency situation, the appropriate emergency response plan will be easly found and provide some guide for emergency rescue.

[4] Dynamic optimization of artificial systems

With the deepening understanding on real-world production system and development of the accident analysis technology, all kinds of modules made up of artificial systems will always be corrected constantly. And the precision of computational experiments will be greatly improved.

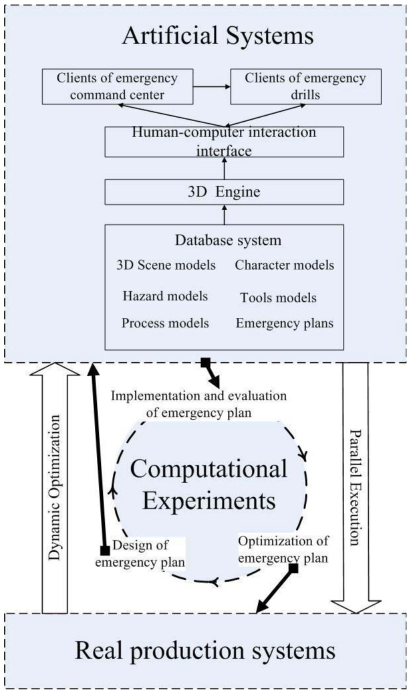

Fig2. Architecture of 3D emergency drills system

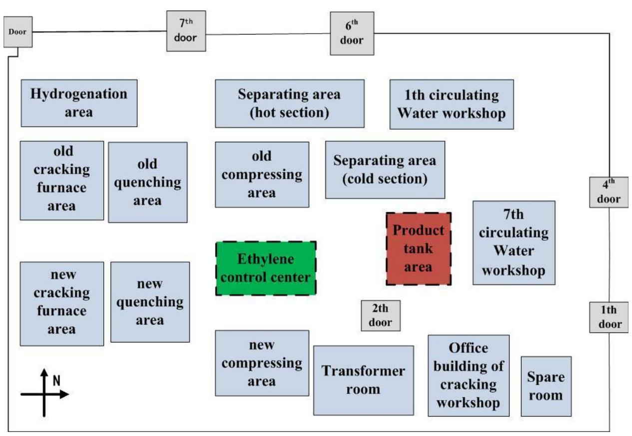

Fig3. layout of cracking workshop

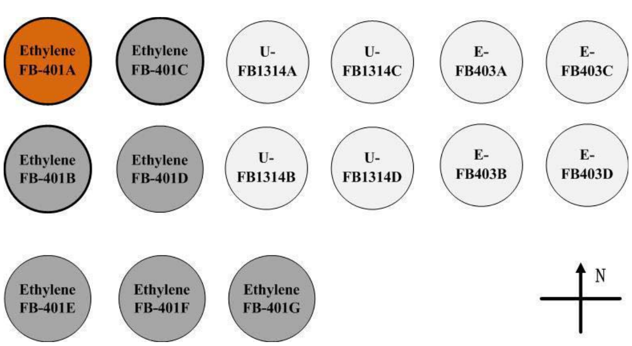

Fig4.layout of storage tank area

Fig 5. 3D Emergency response plans drills system

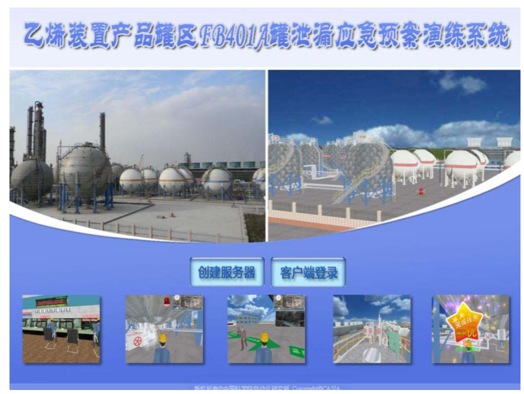

Fig6. A case study of 3D emergency plan drills system

Ⅳ. A CASE STUDY

In this paper, ethylene cracking workshop was chosen as an example to illustrate the feasibility of above system architecture. Figure3 shows the layout of the ethylene cracking workshop in Qilu olefin plant and figure 4 shows the layout of storage tank area of this workshop. At present, the artificial systems of ethylene cracking workshop have been established by the mean of computer technology, information technology and image processing.

Figure 5 displays the 3D emergency drills systems. Next, the operation steps of the system will be introduced by a mock-drills of ethylene leakage accident in storage tank FB-401A. After login, firstly choose the kinds of the emergency response plans wanted to be drilled, for example the leakage of the dangerous chemicals; secondly choose the specific case of emergency response plan, for example the emergency response plan of ethylene leakage in storage tank FB-401A; thirdly set the situation of the accident, such as wind direction: southwest, leak grads: middle rank, whether on fire or not: no fire; finally choose the way of mock-drills, single or collaborative: single. Figure 6 shows the emergency response plan drills system interface of "leakage of ethylene in storage tank FB-401A".

Fourteen mainly steps of mocking emergency drills of emergency response plan of ethylene leakage in storage tank FB-401A are showed in figure 7. The step of 1 to 4 represents inspection operator with tools went to inspect the state of production from the ethylene control center to the storage tank area; the operator found ethylene leakage of the tank FB-401A in the step 5 and timely reported the accident to the chief operator in the step 6; upon the report, the chief operator of separation section timely reported the accident to monitor and monitored the accident evolutions in the step 7; the monitor immediately telephoned to fireman for help ,reported the situation to dispatcher and commanded the operators to handle the accident in step 8 and 9; the step 10 displays how the operator evacuated the unrelated worker on accident site; in the step 11, the operator was setting alerting ropes to isolate ethylene tank area from production systems; in the step 12, the fire fighting vehicle was guided to the fire passage for orders; the step 13 shows the operator was isolating the accident tank from the whole production systems; in the step 14, mock-drills process of this emergency response plan was evaluated.

At present, the above system has passed the test by the experts from petrochemical enterprises in October 2011. The test report was formed as follows: the 3D emergency drills system has the function of emergency response training, emergency drill and evaluation of emergency response plan and can exactly simulation the process of emergency response in full 3D perspective. All the staff related to emergency response can have an intuitive experience of operating in virtual hazardous environment through this system.

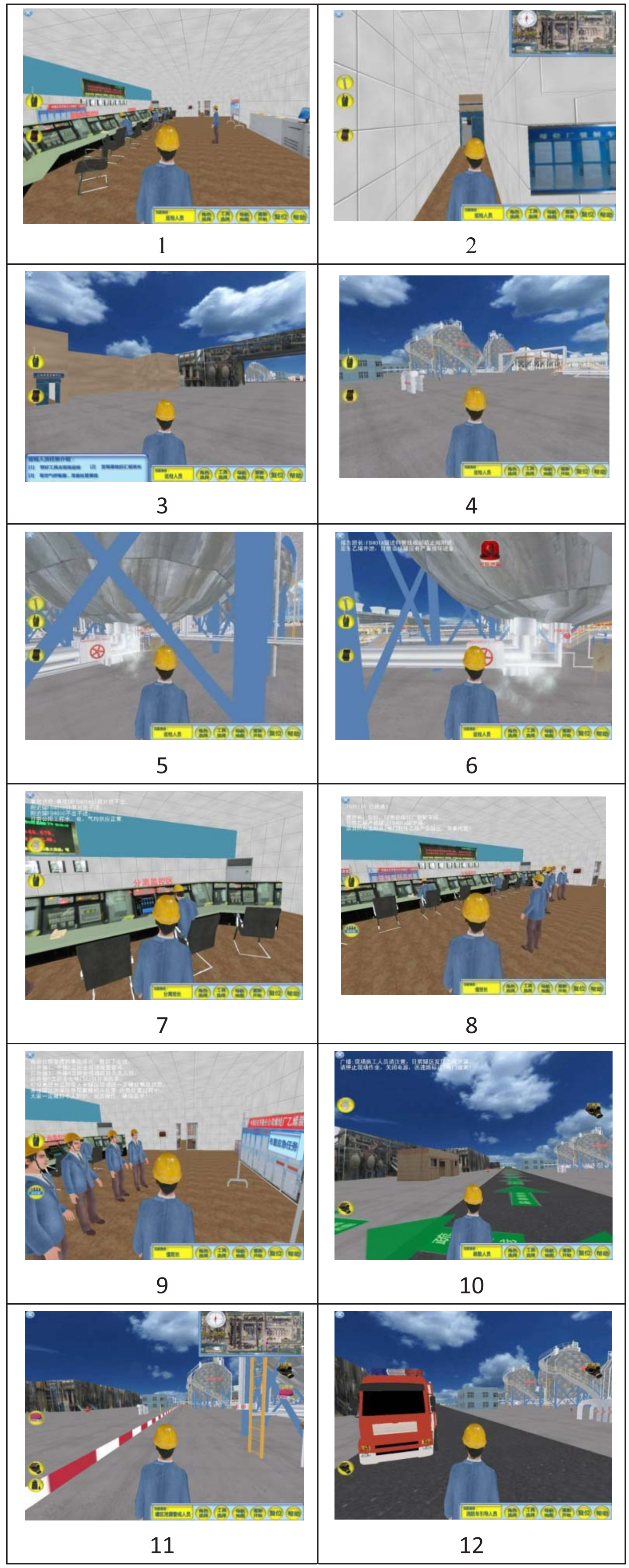

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Fig7 mainly steps of mock-drill

Ⅴ.CONCLUSIONS AND PROSPECTS

In this paper, the framework and the architecture of a 3D emergency drills system were proposed based on ACP approach. And then the system was developed for ethylene cracking workshop of Qilu olefin plant. The usefulness of the system were validated based on a mock-drill of ethylene leakage emergency response plan in storage tank FB-401A. According to the plant's feedback, the system not only meet the emergency responders' training needs in a low-cost and high-efficiency way, but also provide an effectiveness emergency response plan evaluation method for petrochemical plant.

Furthermore, some of changes to be implemented will include an optimization of chemical hazard model to make trainers clearly understand the mechnism of the accident, and expanding this 3D emergency drills system training effectiveness. Also being considered is the addition of artifical intellegency technology to this 3D emergency drills system to increasing the accuracy of emergency response plan evaluation.

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REFERENCES

[1] F. Fiedrich, F. Gehbauer, U. Rickers. Optimized resource allocation for emergency response after earthquake disasters. safety science, vol.35, no.1-3, pp.41-57, June 2000.

[2] G.Z.H.Liu, T.M.Liu. Compiling guide of emergency planning to major accident. Labor protection, no.4, pp.11-18, April 2004.

[3] F.Y. Wang, J.S. Lansing. From Artificial Life to Artificial Societies—New Methods for Studies of Complex Social Systems. Complex systems and complexity science, vol.1, no.1, pp.33-41, January 2004.

[4] F.Y. Wang. Parallel system methods for management and control of complex Systems. Control and Decision, vol.19, no.5, pp.485-489, May 2004.

[5] F.Y. Wang. Computational Experiments for Behavior Analysis and Decision Evaluation of Complex Systems. Journal of system simulation, vol.16, no.5, pp.893-897, May 2004.

[6] F.Y. Wang. Computational Theory and Method on Complex System. China Basic Science. Science Frontier. May 2004.

[7] C.J. Cheng, F.Cui, L.F.Lee. Parallel Management Systems for Complex Productions: Methods and Applications. Complex Systems and Complexity Science, vol.7, no.1, pp.24-32, September 2010.

[8]G. Xiong, F.Y. Wang, M.Yu. Parallel Evaluation Method to Improve Long Period Ethylene Production Management. Control Engineering of China, vol.17, no.3, pp.401-406, May 2010.

[9] Z. Shen, F.Y. Wang and C. J. Cheng. A fuzzy model on how the management affects a worker's State, 2010 IEEE International Conference on Service Operations and Logistics, and Informatics, July 15-17, 2010, Qingdao, Shandong, China.

[10] S.F. Jing, G. Xiong, X. Liu, F. Han, H.L. Zhu: An Analysis of Chemical Accident Scenarios Based on Petri Nets, Conference of Automation, November 26-29 2011, Beijing,China.