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AN OIL PIPELINE TRANSPORTATION WORK-ART EVALUATION EXPERIMENT SCHEMES DESIGN SYSTEM BASED UPON ACTIVITY-ON-VERTICES NETWORK

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Abstract. *Activity on vertices (AOV) network is a nonrecurrent graph which has no negative link weights but has unique source node and destination node. A project consisting of a set of action and precedence relationships can be represented by an activity network. The analysis of the network provides us useful information for managing the project. In this letters, an oil pipeline transportation work-art evaluation experiment schemes design system is developed based upon a revised AOV network. This system is used in the experiment of simulating the process of pipeline transportation and measure the basic characteristics of crude oil under some circumstances conditions.*
Keywords: Activity network, Activity on vertices (AOV) network, Experiment scheme, Evaluation system, Visual experimental program design

1. **Introduction.** In Recent years, it has become more and more important for crude oil transportation by pipelines. The characteristics of crude oil are the key factors for affecting the transportation process. Mostly, crude oil has the characteristics of high waxy, high condensation point and high viscosity [1]. In the procedures of the design, optimization and operation for pipeline transportation, it needs to simulate the pipeline transportation process in laboratory to measure some rheological parameters of the crude oil samples, such as the crude oil viscosity, condensation point, viscosity-temperature curve, yield value, thixotropy and others. These parameters can provide the basis information for crude oil pipeline transportation process [2]. However, the factors affecting the rheological properties of crude oil are manifold. In the past, the simulating lab test for pipeline transportation work-art evaluation, which were conducted by manual, often made the deviation of experimental results with the affect of many interrupt factors. In addition, long-distance pipeline transportation simulation experiments, which are usually carried out more than 20 days, often failed out due to some operator mistakes during the long time and complex experiment processes [3].

Oil pipeline transportation work-art evaluation system is put forward under this background. The system can execute complete automatic control in the process of experiment for a long time and can cope with all kinds of unexpected situations. So, it has fine self-adaptive capacity. Scheme design system which provides some executable experiment schemes is the critical part of this pipeline transportation evaluation system. Experiment scheme, which contains all of the control logic and control parameters, is the key to achieve automatic control of experimental process. Experimental devices carry out experiment under the guidance of the scheme and respond to a variety of emergencies. Control logic of the system is specified by the experiment scheme. This paper will describe the complexity of the experiment process in detail. In order to response to complex experiment procedure, experiment scheme must meet the following requirements.

(1) Unity: It is unity for human-readable and machine-readable.

(2) Logically unique: the actual implementation process is based on the actual situation dynamic variable.

(3) Efficiency: experiment is executed in parallel mode.

This paper proposes an revised activity network method to describe an experiment scheme Based upon the revised activity network, oil pipeline transportation work-art evaluation system is designed. Not only the system can achieve above three objectives, but also it can achieve the goal to automatically generate a variety of modes of experiment schemes. In continent, oil pipeline transportation work-art evaluation system hereinafter referred to as evaluation system.

2. **Evaluation Experiment Systems.** Evaluation system consists of the following components: experiment devices, experiment design and information management software, field control computer and database server. Experiment devices include model oil tanks, pour point meter [4], mixed-packing equipments, sampling equipments and water bath temperature control equipments. Experiment design and information management software is responsible for scheme design and data management. Field control computer is used to analysis plans, issue the specific execution instructions to the experiment devices, and return experiment data at the same time [5]. Database server stores historical data and real time data. This paper mainly describes the experiment scheme design system which is the most important part of the experiment design and information management software.

In order to meet the man-readable function, the experiment scheme design system adopts visualization method. Experiment scheme design system includes the following functional modules: Graphical representation module, program logic module, scheme analysis module, scheme automatic generation module and data access module.

Experiment scheme have different performance models in different modules. It is stored as a table in the database and is presented to the user through data access, logic and graphical representation. While the preservation process is the opposite, the scheme needs to be analyzed before preservation.

(1) Graphical representation of the scheme. It supports various operations including drag, copy, delete and multi-selection. Specific program plan is shown in Figure 1.

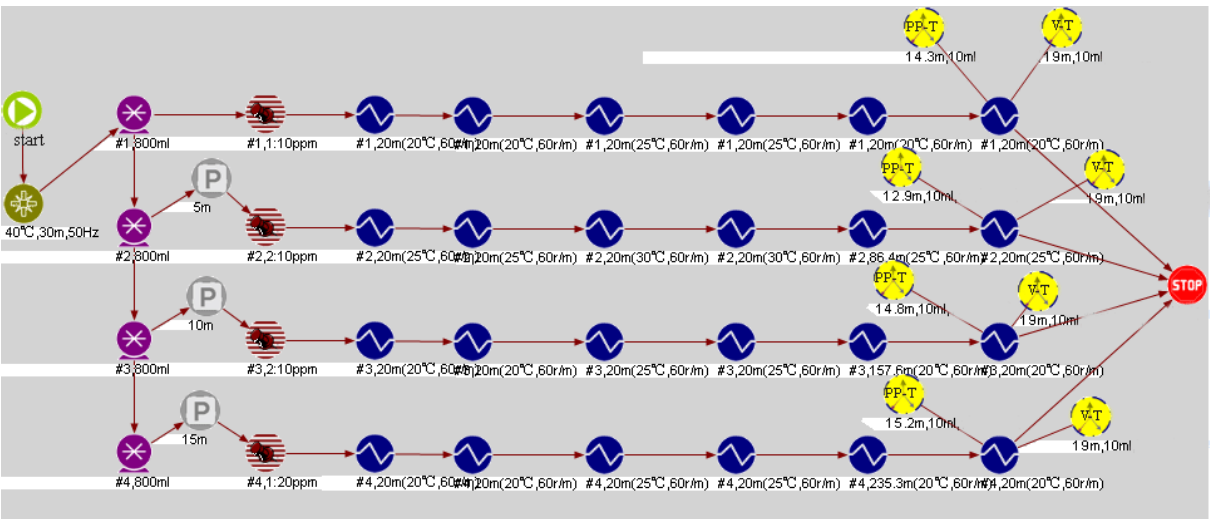

Figure 1. Graphical experiment scheme

(2) Conflict analysis of scheme.

(3) Automatic generation of scheme. The current experiment scheme models of oil pipeline transportation experiment are screening experiments and simulation experiments.

On this basis, the scheme design system provides an open experiment scheme design method for users to draw the scheme directly. Experiment schemes which are in screening experiments and simulation experiments can be automatically generated. Screening experiment is to screen one of the best processing modes in a variety of processing modes to provide a basis for the processing of crude oil pipeline transportation. Simulation experiment is to simulate long-distance transportation of crude oil.

3. The Composition of Experiment Scheme.

3.1. **The relationship between device actions.** Experiment scheme will eventually be transformed into many device actions which contains control objectives and control parameters. In other words, experiment scheme consists of basic information, device actions and actions arrangement. The structure of evaluation system is organized on the basis of the characteristics of experiment scheme. Clarify the relationship between actions is the key in describing an experiment scheme. The relationships between device actions are usually divided into the following three types: Predecessor and successor relation, parallel relation and affiliation.

In fact, the above-mentioned three kinds of relationships exist in a variety of work plans universally. In real life people often use the activity network to describe a plan.

3.2. **Activity network.** When viewing a plan, construction process, production flow, program flow and so on as a project, a project is generally divided into a number of subprojects which are called "activity". Activity network, which is formed by organizing activities with directed edges, is a form of describing the project.

Activity network typically includes the following two forms: Activity on vertices network (AOV network) and activity on edge network (AOE network).

(1) AOV network is a directed graph which uses vertices to represent the activities and uses directed edges to represent the precedence relationship between activities [6,7], it is easy to understand that from Figure 2, in which $C1 - C9$ represents the activities.

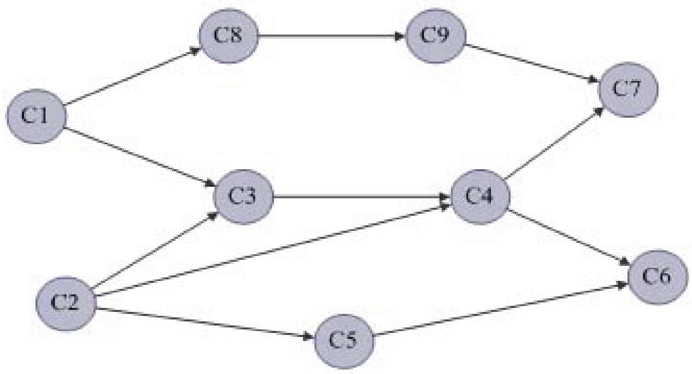

Figure 2. AOV network

(2) AOE network is a directed graph which uses directed edges to represent the activities and uses vertices to represent events [8]. It marks the edges with weights which indicate the cost of this activity. It is shown in Figure 3.

Both AOE network and AOV network are directed graphs, and require that the activity network can not contain any rings. Otherwise the project may not be finished finally [9].

3.3. **Activity network of experimental scheme.** AOE network and AOV network can describe the relation between predecessor and successor, parallel relation among the experiment actions, but it can not describe any actions. As shown in Figure 2, $C3$ and $C8$ is a parallel relation; $C8$ and $C9$ is a relation between predecessor and successor. In order to completely describe the experiment scheme and make it easy to be understand,

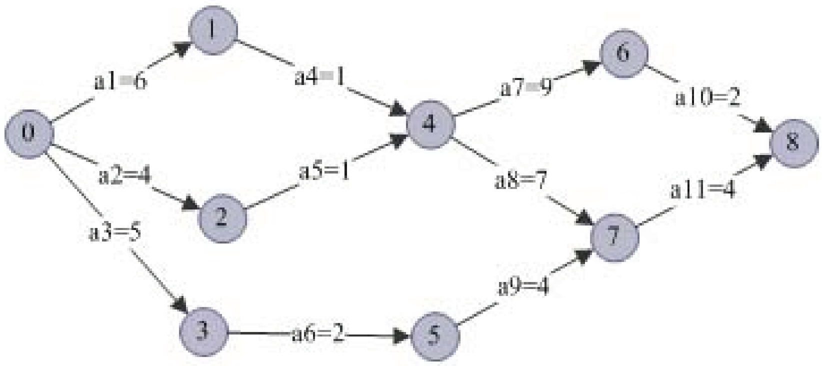

Figure 3. AOE network

we modify AOV network and add undirected edge indicates on the basis of the original. As shown in Figure 4, $C10$ is an affiliation action of $C8$ and $C10$ occur simultaneously. The network which includes three kinds of relations is called full relations network.

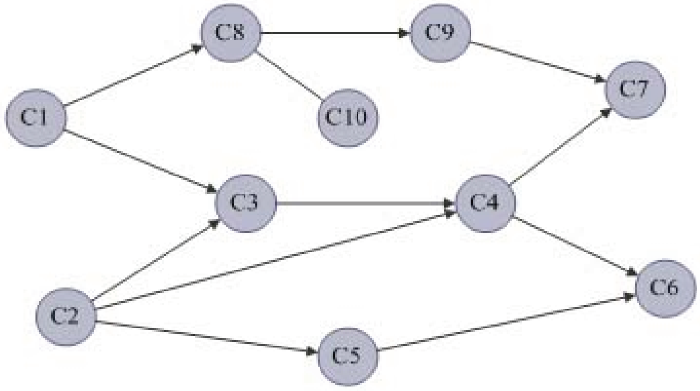

Figure 4. Full relations network

3.4. **The dynamic analysis process of experiment scheme.** An experiment scheme is represented by an activity network. One of the distinctive features of experiment scheme is that the implementing device actions are in parallel, thereby making full use of device resources and improving experiment efficiency. The actual implementation order of experiment scheme actions may be different at each time. The reason is that the experiment scheme only provides the control goal and control parameters of experiment actions, but the actual implementation time of the actions may be different at each time.

The implementation process of experimental scheme can be simply described as the following steps:

(1) Seek actions which have predecessors in non-execution actions;
(2) Open a daemon thread for each action and use threads to send execute commands, and then monitor the implementation of the actions;
(3) If an action is finished, look for the follow-up actions which have not predecessors and then repeat the second step. The thread exit;
(4) Wait until all of the daemon thread exits. The scheme is finished.

4. **Analysis of Experimental Scheme.**

4.1. **Logical checking.** Full network relations do not constrict the relations between actions, but not any combination of device actions can constitute an operating action with according to experiment specifications. Feasibility analysis for experiment scheme is to check whether the network is in line with specific rules.

For a special system, the number of action types is limited. Assuming that A_1, A_2, $\cdots$, A_n are action types of system, the predecessor and successor relation rules which are defined by any two types of A_i, A_j are denoted as $\langle A_i, A_j \rangle$. Affiliation rules are recorded as (A_i, A_j) $(1 \leq i, j \leq n)$. Parallel relation does not need to be limited. The collection which is composed of predecessor and successor relation rules is called predecessor and successor relation rule base. The collection which consists of affiliation rules is called affiliation rule base. The above-mentioned two kinds of rule base does not fully meet the requirements, such as $A \rightarrow B \rightarrow A$ relation is not allowed in experiment scheme, but $A \rightarrow B$ and $B \rightarrow A$ relations are allowed, therefore a supplementary rule base is needed on the basis of the above-mentioned two kinds of relation rule base.

After building relation rule base, it is need to check relations of activity network according to relation rule base to determine that activity network is not against the rules. Specific way is to check whether all the edge of network activity accord with relation rule base.

4.2. **Conflict analysis.** The scheme action is implemented by one or more devices. Due to parallel relation manifest parallel execution in actual execution, it is difficult to avoid the conflict of using the same device at the same time.

There are two reasons for conflict: one is the drawbacks in design of experimental scheme, namely, scheme action complete in an ideal time but has conflict. Another is dynamic conflict generated in scheme implementation. As the action is not necessarily completed in ideal time, there will always be a certain bias. Or due to an action arise exception affected the implementation of the follow-up action, leading to the follow-up action generate conflict. For the former conflict, pre-analysis scheme and improvement of the scheme design are needed to avoid it. For the latter conflict, the dynamic analysis in scheme implementation is needed and appropriate strategies should be used to avoid conflict or mitigate its losses.

It requires an analysis of start time and end time of each action for experiment scheme analysis. In order to analyze conflict situations, it needs to traverse the network activity of scheme. The traversal methods of activity network are depth-first traversal and breadth-first traversal. The traversal algorithm of activity network is in detail here. It is about how to calculate the start time and end time of actions.

Let T_{is} is the start time of action C_i; T_{ie} is the end time of action C_i. The continuing ideal time of C_i is T_i; $C_{j_1}, C_{j_2}, \cdots, C_{j_k}$ are predecessor actions of C_i, then:

$$T_{is} = \max(T_{j_1e}, T_{j_2e,} \cdots, T_{j_ke}), \quad T_{ie} = T_{is} + T_i \tag{1}$$

For C_i with no predecessor action in activity network:

$$T_{is} = 0, \quad T_{ie} = T_{is} + T_i \tag{2}$$

The start time and end time of all actions of activity network can be calculated according to (1) and (2), providing a basis for conflict analysis.

4.3. **Conflict avoidance.** When conflict occurs, it needs to analyze the reasons of the conflict. Adjustment strategy is diverse and the adjustment methods are: in the best possible conditions to meet the intent of the experiment, extending or shortening duration of some actions, or inserting wait action in appropriate place under satisfying experiment purpose possibly conditions. It is very difficult to achieve dynamic conflict avoidance because the biggest problem is how to determine whether the purpose of this experiment is met. As experiment scheme design is off-line, conflict avoidance can be achieved by the aid of manual modification.

5. **Conclusions.** In this letters, the structure of a process experiment evaluation system is proposed, and the composition of the experiment scheme is analyzed. on the basis of

analyzing the characteristics of network activity; a full relation activity network is put forward to describe the control scheme of evaluation system, and the principles and related concepts of logic checking and conflict analysis for experiment schemes is also discussed. The developed system has been used successfully in a real experiment process, and it can well satisfies the requirements for oil pipeline transportation work-art evaluation experiments.

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