Resource Scheduling Solution on Limited Conditions for Parallel Emergency Management System of Manufacturing Enterprises

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Abstract: For the limited conditions problems，such as limited time, constrained resource, and incomplete information, existing in emergency management of manufacturing enterprises, the integrated multi-objective optimization models are created for parallel emergency management system based on ACP approach, and one algorithm is proposed to solve the existing optimization problem. GIS technique is adopted to search the shortest safe path to reduce the damage of the incomplete information. The shortest transporting time and the minimum resource consumption are the optimization objectives in order to solve the problems of the limited time and constrained resource. In addition, the non-dominated sorting genetic optimization algorithm is used to solve the multi-objective optimization problem. Finally, AHP（Analytic Hierarchy Process）is adopted to evaluate the mechanism of emergency parallel management.

Keywords: limited conditions; emergency resource scheduling; Multi-objective optimization; the non-dominated sorting genetic optimization; AHP

1 INTRODUCTION

In recent years, the natural disasters or human-induced emergencies happened frequently, which brought serious economic losses and casualties. Faced with these emergency accidents, the rapid timely emergency response and rescue are particularly significant for the emergency management. For solving the problem, the emergency resource scheduling is regarded as a critical emergency issue, and attracted widespread attention by researchers.

After the actual incident occurred, the emergency resource scheduling is mainly subjected to the three limited conditions. First, the time is limited, which means that it is necessary to provide the emergency resources and supplies as quickly as possible once the accidents occurred. The earlier the resources reach the scene of emergency, the more possible it is to avoid or decrease the casualties and economic losses. So, the time is valuable for the emergency resource scheduling. Second, the emergency resources are limited, especially when the accidents cause serious damage and all kinds of resources are needed. Therefore, in conditions of limited resources, how to deploy emergency resources is significant. Third, information is limited and incomplete, since the important information may be difficult to detect directly in the harsh conditions after the unexpected accidents. Faced with the above limited conditions, how to make the reasonable timely decision on the distribution of resources is a serious challenge.

For these problems of emergency resource scheduling, scholars have made a lot of research.

Reference [1] proposed a decision-making methodology for the dispatching process of urban fire-fighting based on GIS and Petri Nets techniques. Reference [2] gave the model and solution of location and allocation of multi-level emergency resources. Reference [3] constructed Uncertainty optimization model for emergency resource scheduling. Reference [4] proposed a multi-objective dispatch model of emergency management under multi-resource combinations. These research results have made its progress in consideration of the different aspects.

Faced with the three constrained problem of limited time, limited resources, and incomplete information, this paper construct a comprehensive multi-objective optimization model of emergency resource scheduling and give the algorithm to solve the optimization, combined with parallel management systems theory and ACP methods[5-7]. Parallel management systems theory and ACP methods are first proposed by world famous researcher, Professor Fei-Yue Wang, which can be constituted of three parts including Artificial Societies, Computational Experiments and Parallel Execution. 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. This paper is one part in the work, belonging to Artificial Societies.

2 Problem Descriptions

When unexpected incidents occur, decision makers faced with incomplete information, time constraints and other problems. In order to solve these problems, multi-objective optimization models are supposed to be constructed and the effective optimization solution algorithm is needed, in order to provide the decision support to the makers rapidly and effectively.

In fact, the emergency disposal suffers from the constrained conditions frequently, especially constrained time, constrained resource, and incomplete information. The problem of incomplete information is caused by the failure of inspection or telecommunication equipments, which can be offset by the other special equipment. Therefore, the problem is solved by the GIS technique. The objectives of the optimization models are the shortest transmitting time and the least gaps between the resource demand and actual amount of available resources.

3 Emergency Resource Scheduling Model

3.1 Multi-objective Optimization Model

Based on the above problem description, the model is constructed, in which the optimization objectives are the shortest transmitting time and the least gaps between the resource demand and actual resource consumption. The multi-objective model of emergency resource scheduling is as follows:

Supposing that there are existing incidents in M sites, which are represented respectively as $A_i, i=1,2,...M$; emergency resource bases are in N sites, described as $B_j, j=1,2,...N$; each base totally reserves the resource in the quantities of $C_j, j=1,2,...N$; the shortest safety route from the emergency base B_j to the incidents spot A_i is x_{ji}; the resource base allocates the resource of c_{ji} to the accident spot A_i, which needs the total resource of $\overline{c}_j, j=1,2,...M$. Based on the above assumptions, the model is as followings:

$$\min T = \sum_{(j,i)=(1,1)}^{(N,M)} \delta_{ji} x_{ji} \tag{1}$$

$$\min \Delta = \sum_{i=1}^{M} \left(\sum_{j=1}^{N} \delta_{ji} c_{ji} - \overline{c}_i \right)^2 \tag{2}$$

s.t. $\delta_{ji} \in \{0,1\}$

$$\sum_{i=1}^{M} \delta_{ji} c_{ji} \le C_j$$

Where, the shortest safety route is an uncertain variable and can be obtained by GIS (Geo-Information System), which will be described in the next section. $\delta=\{\delta_{ji}\}$ is an optimized variable; $\delta_{ji}=1$ means that there are resources from A_i to B_j.

3.2 The Shortest Safe Route

In this paper, GIS (Geo-Information System, geographic information system) technology is introduced to search the shortest safe route. This technology is able to record the location of all geographic elements and establish their topological relations between the elements [8]. According to this feature, the shortest safe route can be chosen through the analyzing function of the best path in GIS. Meanwhile，the route is influenced by all kinds of complex factors. Generally, the hazardous manufacturing enterprises, especially chemical, nuclear-power enterprises, mostly locate the urban areas with sparse population. The route is affected not only by the degree of traffic congestion, but also by the wind and other natural conditions. Besides, since these factors (such as wind direction, traffic congestion) are time-variant and the information of incident is updated continuously, the route is actually changed and can be regarded as an uncertain variable. For example, if a petrochemical plant happen a gas leakage accident, it’s the shortest safe route is affected by the traffic congestion, the wind direction, the concentration of gas diffusion, whether the route is close to the fire source. If the wind direction is changed, the route has to change with the wind in case that gas-poisoning of rescuers. To solve this problem, GIS needs to construct the optimization model of the shortest safe route for the special application. Moreover, other measures are taken to update the parameters repeatedly and optimize the route frequently, so that the robust is strengthened. When a leakage accident of flammable explosive gas occurs in one a petrochemical olefin plants, the shortest safe route of emergency rescue is shown in Figure 1, in which the red curve is the shortest safe route that can be found on current conditions (northwest wind, no near the fire source, gas concentration is limited within safety value).

Fig 1. The shortest safe route scheme

4 The Multi-objective Optimization

4.1 Multi-objective Optimization algorithm

The Multi-objective Optimization Problem (MOP) can be defined as the problem of finding a vector of decision variables, which satisfies constraints and optimizes the objective functions [9]. MOP is a very important research topic at all times. Because many real-world problems are multi-objective in nature and there are still many open questions in this area. A number of approaches have been suggested to try to solve this problem. In these approaches, Evolutionary Algorithms (EAs) seem particularly suitable, since they can deal simultaneously with a set of possible solutions. Therefore, a lot of Multi-objective Genetic Algorithms (MOGA) have been developed, which can be categorized into three classes [10-11]: Native approaches, Non-aggregating approaches and Pareto-based approaches. The first class is the aggregating method by combining objectives into a single function, e.g. Weighted Sum Algorithm (WSA). The second class is not aggregating and not Pareto-based, e.g. Vector Evaluated Genetic Algorithm (VEGA). The third class is Pareto-based and has been paid the most attention to in Evolutionary Algorithms. In the third class, the famous algorithm is the Non-dominated Sorting Genetic Algorithm (NSGA) proposed by Srinivas and Deb in 1995, which is one of the Pareto-based approaches [12]. In 2000 Deb and others suggested the Non-dominated Sorting Genetic Algorithm II (NSGA-II), which overcomes the shortfalls of NSGA by using a fast non-dominated sorting approach, elitist approach and parameter less sharing [13].

In the paper, NSGAII is adopted to solve the optimization of emergency resource scheduling. In the algorithm, based on the Pareto dominance, Pareto front solutions are obtained instead of one optimum solution.

4.2 Main Loop of the Algorithm

As previous sections, the main loop of NSGAII [13] is as follow:

1) A random parent population P_0 is created, whose number is N, then sort them based on the non-domination sorting.

2) Use the selection, recombination, and mutation operator to generate a child population Q_0, its size is N.

3) Form the combined population $R_t = P_t \cup Q_t$, in number of $2N$. Then, R_t is sorted by non-domination and crowded comparison operator.

4) Select the best solutions of size N as the new parent population P_{t+1}, then use the selection, recombination, and mutation operator to generate a child population Q_{t+1};

5) $t = t + 1$, back step three, until the final conditions are satisfied.

4.3 The results analysis

The results of the algorithm are a group of solutions on the Pareto frontier or approaching the Pareto frontier, instead of one best solution. The solutions are based on the concept of Pareto Dominance which can be described in Figure 2. The solutions, A and B, are on the Pareto frontier, which are superior to the solution C and D respectively. However, the A and B are not comparable. The decision-makers can choose A and B according to the relative importance between objective f_1 and f_2.

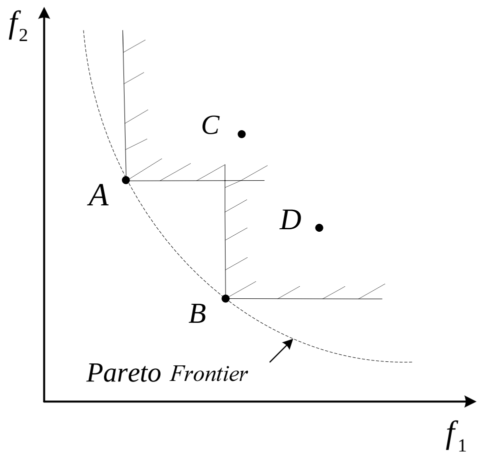

Fig.2 Pareto Superiority Scheme

5 Risk Assessment

For the problems of resource-constrained, time-limited and incomplete information in emergency resource scheduling, the risk assessment mechanism is established to provide the quantitative basis for the decision making, which is significant for the overall emergency. In this paper, AHP (Analytical Hierarchy Process) is adopted, proposed by an American operation researcher, Professor T L Saaty, which is one common analysis method specifying weight [14-15]. This method is a multi-objective decision-making integrating the qualitative analysis and quantitative analysis. In AHP, the complex systems can be decomposed of the various factors, and determine the dominance relationship between each two factors in pairwise comparison, in order to construct an orderly hierarchical structure. Then, the rank of the relative importance of various factors can be determined combined with the expertise, in order to provide the qualitative and quantitative evaluating basis for decision-making. The method is applied to the risk assessments of resource scheduling for the gas leak incidents in the product-tanks area in one olefin plant. The main steps are as follows:

1) Building a hierarchical model. In the gas leak incident, the hierarchical model of the risk assessment of emergency resource scheduling is as follows:

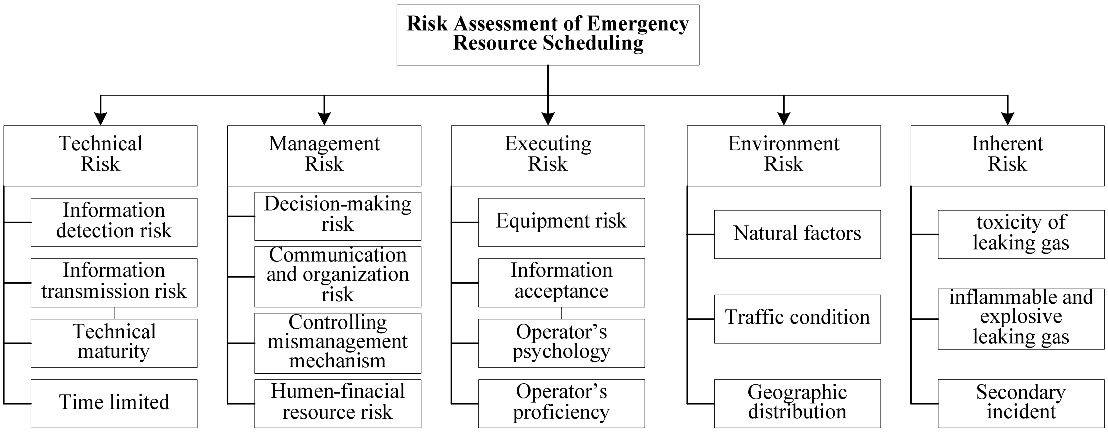

Figure.3 Hierarchical model of the risk assessment of emergency resource scheduling

2) Determining the matrix structure. Professor TL Saaty established criteria from first level to ninth level in the form of matrix. The criteria can quantify the importance of the difference factors in the pairwise comparison, combined with the expertise. In this way, the dominance relationships can be determined between any two factors.
3) Judging the matrix consistency
4) The importance order of all the factors is obtained.

Therefore, the comprehensive risk assessment of the resource scheduling can be attained through AHP to provide the qualitative and quantitative analysis for the decision-making. According to the analysis, the decision maker can take specific measures for the relative significant factors to enhance the reliability and the affectivity of the scheduling solution.

6 Conclusions

The manufacturing enterprises, such as petrochemical enterprises, face severe challenges of in the urgent time, limited resources, incomplete information and others in the emergency resource scheduling. To solve these problems, the paper proposes the solution based on the multi-objective optimization model, in which the objectives are the minimum time and the resource consumption. The technique of GIS is adopted to optimize the shortest safe route. Multi-objective optimization Problem is solved by NSGAII. Finally, AHP is applied to evaluate the risk of the whole solution. The solution is designed for the actual demands of the emergency resource scheduling in the manufacturing enterprises, and it will be improved in the future.

Thanks: this work is supported by: the National Natural Science Foundation (70890084, 60921061, 90920305); Chinese Academy of Sciences project (2F09N05, 2F09N06, 2F10E08, 2F10E10); The starting Fund for the returned overseas researchers (4T05Y03); Cross-cutting projects, the development and application of parallel the management system in Qilu Company olefin plant.

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