THE INTEGRATED RMC DISPATCHING SYSTEM BASED ON THE DISPATCHING CENTER APPROACH

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Abstract: Along with the development of the supply chain for the construction industry, an efficient system that coordinates cement trucks to deliver RMC (Ready Mixed Concrete) to various construction sites becomes important. This paper presents an integrated RMC dispatching model based on the dispatching center approach, which utilizes fast messy genetic algorithms (fmGA), simulation technique, and GPS to automatically and dynamically generate the optimal schedule of dispatching RMC trucks.

Keywords: RMC dispatching, fmGA, GPS, optimization, simulation

1 INTRODUCTION

Along with the development of the supply chain for the construction industry, as one of the key operations within the supply chain, an efficient RMC (Ready Mixed Concrete) delivering process becomes important to RMC batch plants. Because of time limitation of RMC delivery, the RMC plant manager usually needs to consider both timeliness and flexibility while matching up the working processes at various construction sites that call for RMC deliveries. From the business point of view, the RMC batch plant manager may want to dispatch RMC trucks to various construction sites as many as possible to maximize the profits of the plant. However, the job site manager usually wants to avoid discontinuous RMC casting by requiring a substantial number of RMC trucks waiting in queue at the construction site. As a result, when the delivering calls from various construction sites arrive in the same short period of time, it becomes troublesome for the batch plant dispatcher to quickly determine the dispatching sequence of assigning RMC trucks to construction sites. Practically the batch plant dispatcher usually dispatches RMC trucks based on his or her experiences, which usually presents the loss of the potential profits due to the inefficient dispatching schedule. Several studies [1] [2] [3] have recognized the importance of an efficient and effective RMC delivering process. However, their approaches focused on a single batch plant operation only. As many SCM (Supply Chain Management) concepts are incorporated into the operations of the RMC industry, the needs for integrating RMC batch plants are increasing. For example, CEMEX utilizes a dispatching center that coordinates its subordinate batch plants to deliver RMC to various construction sites. However, taking such an integrating approach could also increase the difficulties of developing the efficient and effective dispatching schedules for each batch plant. Therefore, a systematic RMC dispatching model based on the dispatching center approach is essential to help the dispatcher find the optimal dispatching schedules.

This research first explains the SCM concepts applied to the model development, and then incorporates the SCM concepts into building a systematic RMC dispatching model based on the dispatching center approach. This integrating dispatching model allows the dispatching center to take requests from various construction sites and coordinates its subordinate batch plants to process RMC deliveries in the dynamic environment. Several technologies, such as fmGA (Fast Messy Genetic Algorithms), simulation, and GPS (Global Positioning System) are used within the model development. In addition, a computer program called RMCDiSO II (RMC Dispatching Schedule Optimizer II) is developed to help the batch plant dispatcher easy the dispatching process. Results show that this new systematic approach along with the implemented computer program can quickly generate efficient and flexible schedules of dispatching RMC trucks to streamline the RMC dispatching operation.

2. MODEL DEVELOPMENT

2.1 *SCM concepts*

Before developing the systematic model for the RMC dispatching center, several SCM concepts related to the RMC delivering are presented. Among the SCM concepts, JIT (Just in Time), QR (Quick Response), and BTO (Build to Order) are incorporated within the model development.

JIT: RMC needs to be delivered to the requesting construction site as the casting operation proceeds. The ideal dispatching sequence for the batch plant is that the RMC truck arrives at the construction sites as the previous one RMC truck finishes casting, which is a JIT delivering process. However, a JIT delivering process may conflict with the continuously casting if the construction sites manager requires some number of trucks waiting at the construction sites. Therefore, in this model, the total waiting duration of the RMC trucks is minimized so that the whole delivering operation is close to a JIT process.

QR: The time to delivery RMC usually has to comply with the casting operation at the construction site; therefore, such an on-call procedure requires the RMC batch plant to quick response to the customer's needs. Therefore, the RMC truck is assumed to be available for dispatching as soon as it is back to it belonging batch plant and the batch dispatches the RMC truck as soon as the RMC requests arrive.

BTO: Since RMC is produced by various formulas according to the requests from the construction sites, the RMC batch plant can manufacture the RMC only after the delivering request arrives. Such a BTO process requires the RMC batch plant to customize its product to meet the customer's demands because there are no finished products on stock. Therefore, in this model, it is prohibited for the dispatching center to redirect RMC trucks with loaded concrete to the other construction sites unless those construction sites require the same grade and amount of concrete.

Furthermore, the dispatching center that coordinates various RMC batch plants to delivery RMC to construction sites has became the call center of the RMC delivering operation. All RMC delivery requests from the construction sites are processed through the dispatching center. The dispatching center can direct RMC trucks from various batch plants to the requesting construction sites. These aforementioned SCM concepts are incorporated within the model development described in the next sections.

2.2 The dispatching center systematic model

In this study, the factors that impact the RMC delivering process are adopted from [3], in which a detailed discussion of the RMC delivering process is provided. The input factors are the number of the RMC deliveries, traveling duration between the batch plants and the construction sites, the casting duration at the construction sites, and the duration of mixing concrete. The process of determining the optimal dispatching schedule for each batch plant is performed by simultaneously applying fmGA and CYCLONE. fmGA searches through the possible dispatching schedules within the solution space by minimizing the total waiting duration of RMC trucks. The waiting duration of RMC trucks for a dispatching schedule is determined by simulating a CYCLONE model that describes the delivering process. Two constraints−continuously casting and the capacities of the batch plants are also employed within the CYCLONE model to screen out the infeasible dispatching schedules which are generated by fmGA. In addition, GPS is applied to get the dynamic operative information of each RMC truck. The dynamic operative information of each truck is used to check whether the actual delivering process deviates from the simulated process of the optimal dispatching schedule. If the deviation of the process is over certain value, the dispatching schedule will be re optimized automatically. Figure 1 shows the scheme of the RMC dispatching system. The technologies applied in this dispatching model will be explained in the followings.

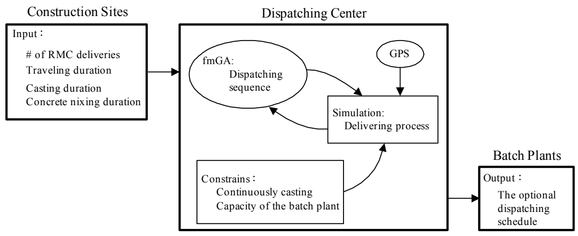

Figure 1. The scheme of the dispatching model

2.2.1 fast messy genetic algorithms

From the above development of the RMC dispatching model, it is clear that the efficiency of the RMC dispatching schedule depends on the dispatching sequence of the RMC trucks. The dispatching sequence of the RMC trucks can be treated as the permutation of the RMC deliveries from which batch plant to construction sites, which is similar to the typical traveling salesman problem (TSP) except construction sites are visited more than once. As it can be expected, the solution space could be explosively increased if the number of the batch plants, the construction sites, and required RMC deliveries increase. Therefore, the fmGA is employed to search for the optimal dispatching schedules. The total solution space of dispatching schedules can be determined by Eq. (1)

$$TS = \frac{\left(\sum_{j=1}^{m} K_j\right)!}{\prod_{j=1}^{m}\left(K_j!\right)} \times n^{TN} \tag{1}$$

Where

TS：Solution space

*K*j：RMC deliveries requested by the construction site j

m：number of the construction sites

n：number of the batch plants

$$TN = \sum_{j=1}^{m} K_j$$

The fast messy genetic algorithms (fmGA) were developed by Goldberg et al. in 1993 [4]. Unlike the well-known simple genetic algorithms (sGA)" [5] [6] [7] which uses fixed-length strings to represent possible solutions, the fmGA applies messy chromosomes to form strings of various lengths. The fmGA can efficiently find the optimal solution of the large-scale permutation problem [8]. In addition, the GA-based approach has been known for its flexibility in hybridizing with other methodologies to obtain better solutions [9]. Since the departing time of each truck assigned to various construction sites is obtained by simulating the delivering process, the fmGA is adopted to integrate with the simulation methodology to find the dispatching sequence of the optimal dispatching schedule in this study. The elements and the process of the fmGA are briefly described in the following:

2.2.2 messy representation

In the fmGA, genes of a chromosome are represented by the pair (allele locus, allele value), in which allele locus indicates the position of the gene and allele value represents the value of the gene in that position. For example, two messy chromosomes ((5 0)(1 0)(3 1)(4 1)(2 1)(4 0)(5 1) and (3 1)(1 1)(5 0) may be both equivalent to the binary string 01110. As the above example shows, messy chromosomes may be "over-specified" and "underspecified" in terms of encoding bid-wise strings. Chromosome S1 is an over-specified string which has two different values in the positions of genes 1, 4, and 5. To evaluate the over-specified chromosome like S1, the string may be scanned from left to right with the first-come-first-serve rule. On the other hand, for evaluating the underspecified chromosome, such as S2, the competitive template is used. The competitive template is a problem-specified and fixed-bit string that is randomly generated or the solution found so far within the searching process.

2.2.3 messy operators

Messy operators that include the cut-splice operator and the mutation operator are used as genetic operators in the fmGA. The cut-splice operator, similar to the crossover operator in the sGA, is used to recombine different strings to create new strings. For example, as shown in Figure A cut at point 3 would result in strings ((2 0)(5 0)(3 1)) and ((6 0)(5 1)). The splice operator joins two strings with a specified splice probability Ps. For example, as shown in Figure 2, two strings ((2 0)(5 0)(3 1)(6 0)(5 1)) and ((1 1)(2 1)(4 1)) would be recombined to ((2 0)(5 0)(3 1)(4 1)) and ((1 1)(2 1)(6 0)(5 1)) after being cut and spliced.

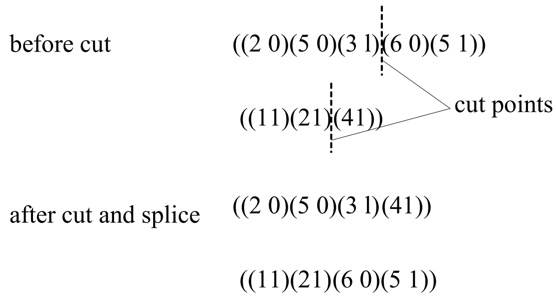

Figure 2. Cut-splice operator

The mutation operator perturbs the allele values of the messy chromosome by switching them from 1 to 0 and vice versa with a predefined probability Pm, which is similar to the mutation operator used in the sGA.

2.2.4 organization of the fmGA

There are two loops, the outer loop and the inner loop, within the fmGA. The outer loop iterates over the order *k* of the processed Building Blocks (BBs). Every cycle of the outer loop is denoted as an era. When a new era starts, the inner loop which includes the initialization phase, the primordial phase, and the juxtapositional phase is invoked. The goal of the initialization phase is to create a population of strings containing all possible BBs of the order *k*. The primordial phase filters out the "bad" genes not belonging to BBs so that the population encloses a high proportion of "good" genes belong to BBs. Two operations, the building-block filtering and the thresholding selection, are performed within the primordial phase. In the juxtapositional phase, those good genes are combined by using the selection and the messy operators to form a high quality generation which perhaps contains the optimal solution. When the inner loop of the fmGA terminates, the outer loop of the fmGA begins with processing the BBs of order k+1. In addition, the competitive template is replaced by the best solution found so far, which becomes the new competitive template for the next era. The whole process is repeated until the maximum number required k_{max} is reached. The organization of the fmGA is shown in Figure 3.

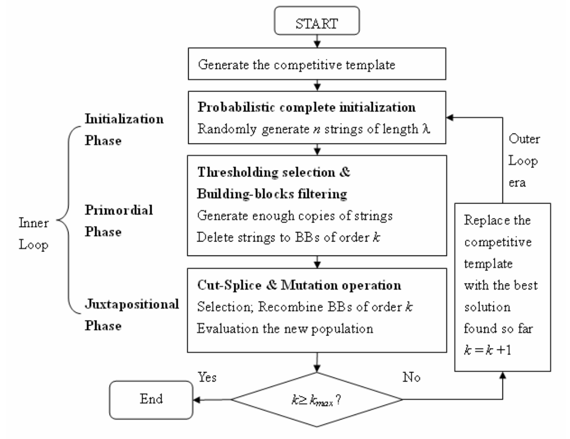

Figure 3. Organization of the fmGA

2.2.5 messy chromosome structure

The purpose of using the fmGA is to find the most efficient and effective dispatching sequence of RMC trucks from the batch plants which are subordinate to the dispatching center. Since the required number of the RMC trucks can be determined, various dispatching sequences can be treated as the permutations of assigning RMC trucks to various construction sites. Therefore, the chromosome structure is designed so that all permutations can be represented and evaluated.

First, the length of the problem is denoted as the total number of the RMC trucks that will be dispatched from the RMC batch plants at the same short of time. Since the messy chromosome representation allows strings to be "over-specified" or "underspecified", the length of the problem is used to determine the length of the competitive template only. Each messy gene within the chromosome, as shown in Figure 5, consists of three variables which identify the gene position, the ID of the batch plant, and the ID of the construction site, respectively.

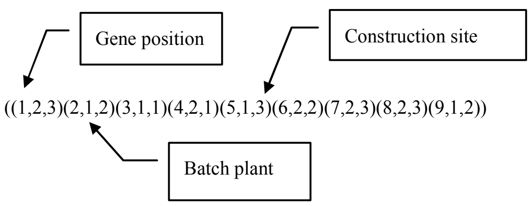

Figure 5 the messy chromosome

2.3 Simulate the delivering process

It is important that the dispatching schedule should comply with the casting processes at the construction sites. However, the number of RMC trucks that the each batch plant owns is limited; it is possible that the batch plant cannot dispatch RMC truck because no trucks have been back to the batch plant. In addition, the dispatching schedule should satisfy the constraint of continuously casting. Therefore, it is necessary to simulate the whole RMC delivering process to screen out the infeasible dispatching schedules. In the field of construction management, there are several custom-developed simulation packages specially designed for applications in construction projects. Among them, CYCLONE is one of the widely used simulation technologies because of its clear and simple symbolic structure [9]. In this research, a CYCLONE model, as shown in Figure 6, is built to simulate the delivering process. The information obtained from simulating the RMC delivering process, such as the waiting time of each truck at various construction sites and the idle time of various construction sites, are used to evaluate the efficiency of the dispatching schedules.

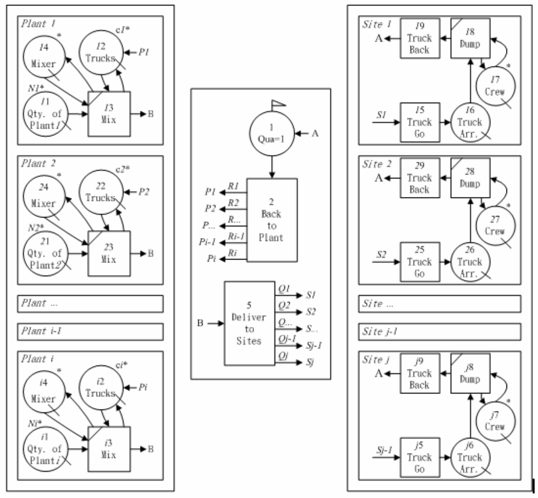

Figure 6. The CYCLONE model

2.4 The dynamic operative information

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. In this RMC dispatching system, the actual operative information of each RMC truck, such as casting time at the construction site, is transformed from the GPS data. The actual operative information is used to check whether the RMC delivering process is matched with the simulated optimal dispatching schedule. Once the deviation between the actual and the simulated delivering processes is over certain value, the dispatching schedule will be re-optimized automatically. In addition, since constantly retrieving GPS data is costly, a bundle service provided by the Chunghwa Telecom is employed in this study. A particular feature of this bundle service is that the GPS data can be obtained through the Internet. By taking this approach, the overall quality of GPS data retrieving can be assured. In addition, the cost of retrieving GPS data is minimized. Figure 7 shows the GPRS-based GPS provided by the Chunghwa Telecom.

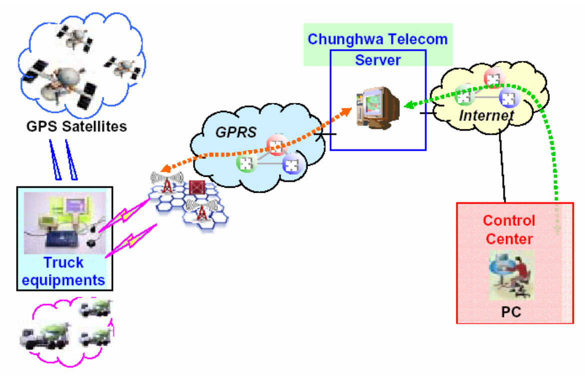

Figure 7 The GPRS-based GPS (from the Chunghwa Telecom)

3 THE RMCDISO II PROGRAM

The computer implement called RMCDiSO II (RMC Dispatching Schedule Optimizer II) is developed based on the above mentioned dispatching model. Figure 8 is the interface of RMCDiSO II. RMCDiSO II consists of three sections "Input Data", "Processing Data", and "Output Data". "Input Data" allows the users to enter the related parameters of the dispatching system, fmGA optimization, and CYCLONE simulation. "Processing Data", as shown in Figure 9, contains the optimization results and the GPS information of the RMC trucks, in which user can know how the optimization is performed. "Output Data" shows the results of the optimal dispatching schedules. As shown in Figure 10, Users can click on any of the batch plant to see the dispatching sequence of that particular batch plant. With the development of RMCDiSO II that integrates the fmGA, the CYCLONE simulation, and GPS, the process of determining a good schedule of dispatching RMC trucks to various construction has become been efficient and effective.

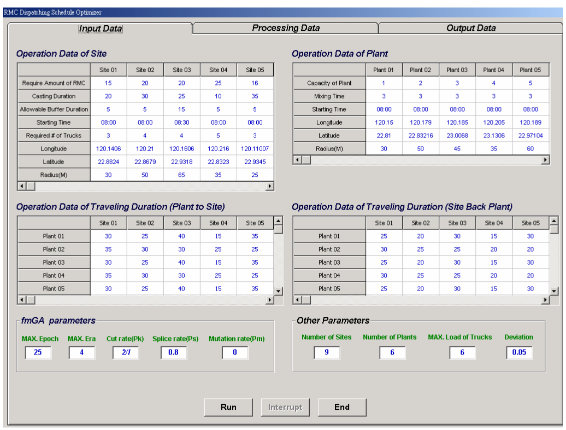

Figure 8. The interface of RMCDiSO II

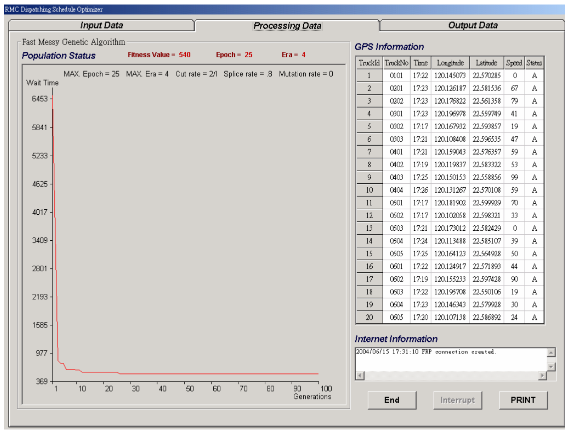

Figure 9. The data processing interface

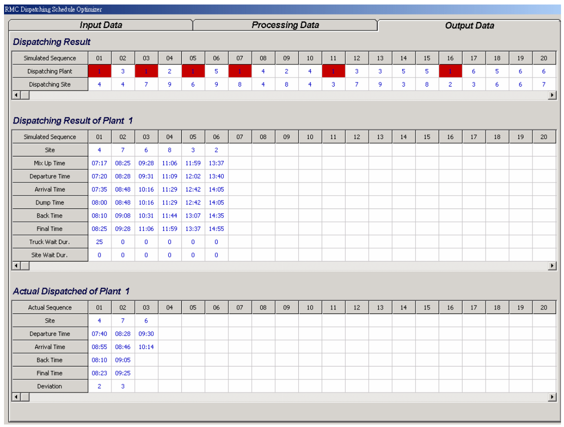

Figure 10. The result of the optimal dispatching schedule

4 CONCLUSIONS

Efficient delivery of RMC to the construction sites is one of the key operations to the RMC industry. Along with the development of the supply chain for the construction industry, a good dispatching schedule becomes more and more important. This paper presents an integrated RMC dispatching system based on the dispatching center approach. Results show that by applying the fmGA and the simulation technique to the proposed RMC dispatching model, the dispatcher at the dispatching center can quickly generate efficient and flexible schedules of dispatching RMC trucks for its subordinate RMC batch plant. In addition, the practice of the integrated dispatching system developed in this research is enhanced by employing RMCDiSO II which integrates the fmGA, the CYCLONE simulation, and GPS.

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