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An adaptive scheduling system with genetic algorithms for arranging employee training programs

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Abstract

An outstanding human resources system is one of the important competitive factors in modern enterprises. Employee training is a frequently used method for promoting the working capabilities for better human resources. Employee training programs cultivate personnel capabilities for enterprise operation. The training effect can be dramatically enhanced if curriculum is well designed and arranged. However, arranging curriculum is a difficult and lengthy task which enterprises traditionally devote a large amount of human and material resources to. We improved the process by proposing an optimal curriculum arrangement model in maintenance personnel training programs, and utilizing genetic algorithms as solution procedures. An adaptive computer aided training system for maintenance representative training was also developed to facilitate personnel training for machine tool industry.

Keywords: Curriculum scheduling; Optimization models; Genetic algorithms; Computer aided training system

1. Introduction

In modern enterprises, an outstanding human resources system is an important competitive factor, and employee training is a key method for promoting the working capabilities for better human resources. In order to operate a business for sustainable development, the employees training activity is crucial (Liang, 1994). The issue of employee training in enterprises originated from the concept of human resource development (Lin, 1994). Human resource development is not only a kind of quality improvement for human resources, but also the way of increasing organizational efficiency, productivity and profit. In addition, employee training can inspire human capability, increase staff accomplishments, and raise individual and organizational effect. Employee knowledge, techniques, and capability can be improved by employee training and educational learning activities (House, 1967).

From the viewpoint of modern education training, which emphasizing individual differences and diversity, traditional training styles neither meet the requirements nor make an efficient enterprise training program (House, 1967). The traditional methods of education and training focus on verbal training of beginners by experienced employees. These methods are time-consuming and inefficient, therefore, especially for frequent employee turnover, instruction with experienced employees is hardly practical.

Since computer-assisted instruction (CAI) was introduced in 1960, its development has gradually shifted from repeated teaching system to intelligent tutoring system (ITS) and individualized instruction (Farley, 1981). Yan (1995) contends CAI that systems which adjust the quantity of the instructional materials are better than those which do not. Ross (1984) also states that an adjustment system that controls the quantity of instructional material can increase teaching efficiency, and with the strategy of

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instructional material control, the controlled system is better than one that is self-controlled by the trainees, which does not provide diagnosis or suggestions. In the self-controlled system, the trainees control the learning course without the benefit of experience, not knowing their own strengths and weaknesses. In addition, the course scheduling system can also become personalized and popularized through the Internet, utilizing web browsers to provide channels for systematic interactions (Lin, 1998).

Many specialists believe that the effects of training can be dramatically enhanced if a curriculum is well designed. In training systems, scheduling adequacy is crucial to the system. Specifically, the ability to schedule appropriate training courses is an important function of a training system. By utilizing reasonable functions of the training program, such as adaptive course arrangement, this training system can be more practical. Therefore, we intended to focus on appropriate course scheduling and arrangement.

The Taiwanese machine tool industry is one of the most important industrial activities on the island. However, employee training for most companies in this sector was performed in conventional means. There is no systematic course scheduling mechanism utilized in the training practice, which results in time-consuming processes and less training achievement.

In this study, the maintenance personnel training in machine tool industry was taken to illustrate the formulation of mathematical models. The optimization model we proposed is capable of handling training course scheduling, which provides optimal course combination for triggering adequate training materials. The training programs of the machine tool industry are collected and organized as well. The objective of this study is threefold: (1) to construct a mathematical model with adequate course arrangement, (2) to solve the model with genetic algorithms for obtaining optimal results, and (3) to develop a computer aided training system to facilitate personnel training in the machine tool industry.

2. Literature review

In order to search for suitable training course that meets individual needs, this study discusses the scheduling of training courses, the attributes of courses, the construction of a scheduling model, and GA, which was utilized to solve the model.

2.1. Scheduling and selection of course

Many studies have been found in the literature that deals with course selection and scheduling in training programs. Chiou (2002) stated that course scheduling is a complicated issue and is an NP-Complete problem. There is no optimal solution in the programming search area. Lin (1998) contended that the complexity and difficulty of the course scheduling is caused by the uncertainty of the correlation between the resource limitations and multiple constraints. The issue of course scheduling is a Constrain Satisfaction Problem, CSP, which obtains sufficiently feasible solutions but has difficulty reaching the optimal solutions. Alvarez-Valdes, Enric, and Tamarit (2002) designed and implemented a course scheduling system with Tabu search algorithm. Yan (1995) suggested a dynamic instruction strategy system after designing the learning flow of the computer assisted learning system for students, analyzed the addition operation within 1000, and built complete instructional materials for the addition operation. Yan also used fuzzy set theory to provide the qualified grading method for teachers, while using GA to modify the learning flow. That dynamically adjustable learning flow system can control the quantity, sequence and content of the instructional materials, according to the needs of the students, which realizes the educational goal of individualized teaching. This method is more appropriate for the procedural courses. However, it is still difficult-to-reality in maintenance personnel train programs since it is time-consuming. This method requires a test immediately after the course is taken, and with the test results, the system modifies the structure of the instructional materials. The system then uses genetic algorithms to search for the next suitable course. However, it needs much time to achieve good results while the number of course unit getting large. Besides, since the personnel training courses mostly are not procedural, this method is not suitable to be utilized for training purposes.

Lin, Wu, Perng, and Tsai (1998), Lin, Han, Tsai, and Perng (1998) suggested the use of fuzzy set theory to select training courses. They considered the factors of the emotion and ability of the trainees, using the characteristic of the fuzzy set theory in accordance with the factors of emotion and ability to modify the attribute values of the course (such as training period), and recommend a course sequence. Their research overlooked the procedure of the training, and could not meet the demand for the course preparation.

Chiou (2002) used genetic algorithms to solve a mathematical model for structured course scheduling, and suggested a unique bi-matrix, according to heuristics, to produce solutions that initially satisfied requirements. Based on the requirement for model adjustment, Chiou applied genetic search procedures for finding optimal solutions, demonstrating the great search ability and efficiency of GA. However, Chiou's approach did not take the course attributes into account.

2.2. Employee education and training

The ideal policy of the employee training of an enterprise should cover education, training and development. In accordance with concept of life-long learning, employee training programs need systematic planning and proper course design. Education refers to focusing on the potential needs of the enterprise, and through long-term training, helping the individual gain general knowledge. Training should emphasize the immediate needs of the enterprise, help the individual obtain professional knowledge according to the concept of "learn now and apply immediately." Development means to broaden the ideas and increase the ability as a whole through long-term cultivation (Liu & Lee, 1995).

Matsushita Konosuke, a famous Japanese manager, once said: "Foster people before making products (Lin, 1998)." Because people are the basic element of the enterprise activities, many visionary managers or administrators, in addition to focusing on the achievement of the short-term mission goals, under the circumstances of limited time and funding, are committed to increase the quality of the human resource (Weaver, 1988). The education and training directors vary by the scale of the enterprise, departmental categories and the directions of the managers. Generally, enterprises with a larger scale have the independent departments to hold organized and systematic training for all employees. The training lecturers are both internal and external corporation. The internal lecturers are responsible for the internal training of the company, while the external lecturers for the external training. The training scope includes employee special technology, skills and knowledge development, attitude changing, motivational education and the improvement of working-willingness. The subjects of the training are hierarchically separated as managing level, supervising level and operating level. In addition, the methods of training are categorized as on-the-job training (OJT), off-the-job training (Off-JT), and self-development (SD) (Lin, Chang, Tsai, & Perng, 1996). We focused on the training of the operating level employees only. That is, the model of training program arrangement was considered and formulated for operator-level employee training under OFF-JT environment.

2.3. The computer technique for education and training

Computer-assisted instruction (CAI) was developed in the 1950s, using second-generation computer as tools. In 1960, the PLATO system of the University of Illinois was a CAI system for student education. In the 1960s, it developed branch programs that, according to the levels and reactions of the students, enabled self-control for flow of the instructional materials and selection of the learning materials, moving toward the individualized teaching. However, the users were limited to students in universities, a few companies and military facilities. In the 1970s, with the increasing use of microcomputers, the development of CAI system became popular (Ho, 1994). Cloete (2001) defined an electronic educational system model (EES model) as being one that assisted designers of different e-learning settings to plan and implement a specific learning situation, with the focus on the individual requirements and milieu of the learning group. The EES model is composed of four layers, each consists of different components addressing issues specific to each layer. When constructing a learning situation, the planners, schedulers and facilitators come together with a clear view of their particular learning situation in mind. They then use the EES model to design their course, layer by layer, including objects from each layer. Each object consists of one or more strategies to be implemented in order to achieve the learning objectives of the courses. This approach promises to increase the chances of successful quality and implementations.

Robinson, Lester, and Hamilton (1998) proposed a web-based method to facilitate teaching material transformation between different computer platforms. They designed teaching material utilizing web pages enhanced with Java applets, MPEG video clips and dynamic HTML. Gable and Page (1980) divided teaching design with the modern educational technology into four steps. Step one is programmed instruction, in which the instructional materials are divided into tightly connected learning units. Learning the previous unit is a prerequisite for progressing to the next unit, and all course units are connected sequentially. Step two is scrambled textbook using branching strategy. After the student answers a question, the system, in accordance with his or her choice, will jump to another learning unit. Step three is adaptive courseware, which introduces the concept of the adjustable course. The adjustable course ensures that the branching of the course is not only in accordance with the specific choice the student made on a certain question, but also the combination of the total performance of the student. And step four is generative, where the instructional materials are analyzed by artificial intelligence (AI), focusing on the needs of the student to create the most suitable materials (Liu & Lee, 1995).

Computer-managed instruction (CMI) was first introduced in the early 1970s (Lomerson & Knezek, 1991). Baker defined CMI as using computers to manage the teaching activity for individualized students (Alvarez-Valdes et al., 2002). Leiblum suggested many instructional and administrative functions for a CMI system such as setting the instructional objectives, arranging the instructional materials, providing tests and reporting learning progress (Leiblum, 1982). A CMI system is employed to manage teaching activities and knowledge through the use of computers. To be more specific, CMI is able to manage the teaching activity for knowledge, rather than to manage the teaching activity for skills and emotions. As the development of the information and communication technology, the design and application of CMI are improving and approaching to the ideal situation of individualized teaching. In the future, the goal for individualized education and training is to combine with the AI technology for administrative teaching and to implement the educational concept of the adaptive learning (Juang, 1996).

2.4. Genetic algorithms

Genetic Algorithms are adaptive heuristic search algorithms premised on the evolutionary ideas of natural selection and genetic. The basic concept of GA is designed to simulate processes in natural system necessary for evolution, following the principles of Darwinian evolution. Pioneered by John Holland in the University of Michigan, GA was shown to be an effective search algorithm (Lin, 1995; Lin, Zhang, & Wang, 1995, 1997). It has been widely studied, tested and applied in fields of management science and engineering. In a comparative study, for example, Lin et al. (1995) compared five optimization algorithms for engineering problems and found that GA outperformed other optimization algorithms.

Using GA to solve the optimization problem, the objective function must be formulated to be a fitness function, which represents the fitness of a system to its outside environment, as the performance index of system. If the value of this fitness function approaches the optimization goal, the system performance is better. GA has developed to find the optimization solution with fitness by some of artificial operational process, which simulated natural selection and genetic, such as reproduction, crossover, and mutation. The basic principle of GA has developed from the simple genetic algorithm, SGA (Goldberg, 1989). GA is applied in a wide variety of research fields and is shown capable of finding optimal solution rapidly (Arroyo & Armentano, 2005; Chang & Chung, 2005; Elegbede & Adjallah, 2003; Kumral, 2005).

3. Course structure analysis

For a trainee with limited training time, it is very important to receive the training as efficiently as possible. The available training time should be considered. The course combination is also configured according to each trainee's knowledge and abilities. Furthermore, some courses with multiple knowledge aspects do not belong to only one category. For instance, a course on machine fault diagnosis utilizes many skills or knowledge to accomplish a diagnosis job, so the training material should be assigned specifically to reflect the characteristics.

The courses should be procedural for effective employee training, so trainees should take the training courses one by one, from lower levels to higher levels. However, this may not actually be true in training if the courses are not well constructed or the trainees need only applied skills. In the general enterprise training practice, most of the trainees already have basic concepts of the training subject, and only need further applied knowledge. Therefore, the training courses could be implemented focusing on applied skills, and not according to a clear procedure.

Weaver (1988) designed a training course, based on indicators of learning difficulty and importance, and found that more complex knowledge is, more difficult to learn, and this takes more time. Weaver defined the structure of course unit for knowledge analysis as four indicators: separability, complexity, importance and practicability. We modified Weaver's indicators due to industrial practice. Each training course was assigned attribute values according to course significance, frequency, level, and training time.

Table 1
Course structure for training program

Course i	
Course attribute	Membership value
Significance: W_i	Membership value to course category j: P_{ij}
Frequency: F_i	
Level: L_i	Membership value to machine type k: M_ik
Training time: T_i	

The training courses in machine tool companies can be separated into three content categories: machinery, electricity and operation, based on designated maintenance tasks. Furthermore, two general course categories are aided for a complete course spectrum: programming and general. The manager expects the maintenance representatives to learn as many professionals as possible and is capable of fixing all models of machines. We considered course structure and the content of course to machine type. The structure of the educational training course is designed as shown in Table 1.

There are totally 212 training topics collected and 30 units of them were taken to illustrate the configuration of course attributes. The membership value for each course related to category and machine type were set by domain experts in the human resource department. The course was categorized by two machine types; M_1 and M_2, and three content categories, namely, machinery, electricity and operation. Table 2 shows the attributes of 10 courses and the value for each attribute.

4. Formulation of optimal course arrangement models

4.1. Objective function

The optimization model we proposed for adaptively arranging training courses to meet training purpose was formulated. The objective function is shown as Eq. (1). The objective is to maximize the scheduling utility, in terms of course attibutes and training demand.

$$\text{Max} \quad \sum_{j=1}^{n}\sum_{i=1}^{m}(G_iP_{ij}W_iF_iS_j) \tag{1}$$

The notation is described in the following:

1. G_i denotes the status of the ith course has been scheduled or has not been assigned, which is 1 or 0 respectively. In another words, $G_i = 0$: the course is not arranged; and $G_i = 1$: the course has been scheduled, $i = 1, 2, \dots, m$, where m is the total number of training courses (units).
2. P_{ij} represents the membership value of course to the category. Specifically, P_{ij} is the value for course i designated to category j. The weight was assigned by a domain expert or a course analyst. For example, the categories of machinery, electricity, and operation are represented by values of 1, 2, and 3 respectively. The membership

Table 2
Course structure and attributes

Code	Course title	Course category and membership degree			Membership of machine type		Significance	Frequency	Level	Training time
		Machinery	Electricity	Operation	M_1	M_2				
1	Introduction to cutting tools	1.0	0.0	0.0	1.0	1.0	0.8	0.6	1	25
2	Introduction to Robotics	1.0	0.0	0.0	1.0	1.0	0.6	0.5	3	20
3	Adjusting cutter grasper	0.0	0.0	1.0	1.0	1.0	0.7	0.3	2	30
4	Adjusting tool magazine	1.0	0.0	0.0	0.2	1.0	0.5	0.8	1	30
5	Trouble-shooting transmission box Type I	0.5	0.0	0.5	1.0	0.0	0.4	0.4	2	20
6	Trouble-shooting transmission box Type II	1.0	0.0	0.0	0.0	1.0	0.9	0.9	3	20
7	Introduction to Robot M2325	0.6	0.4	0.0	1.0	0.5	0.2	0.4	1	30
8	Serial and parallel circuit	0.0	1.0	0.0	1.0	1.0	0.9	0.5	1	20
9	Ohm's law	0.0	1.0	0.0	1.0	1.0	0.9	0.4	1	10
10	Stepping motor inspection	0.0	1.0	0.0	1.0	1.0	0.5	0.8	2	20

value of course i to the course of machinery, electricity, and operation are represented with P_{i1}, $P_{i2,}$and $P_{i3.}P$'s are assigned membership values of a specific course according to its content. $0 \leqslant P_{i1} \leqslant 1$, as well as P_{i2} and P_{i3}. $P_{i1} + P_{i2} + P_{i3} = 1$.

3. W_i indicates the importance of course i, in terms of fulfillment level of accomplishing maintenance tasks or close relationship with other courses.
4. F_i shows the usage frequency of the course i. High frequency represents frequent application of knowledge or technique in the work place. $0 \leqslant F_i \leqslant 1$.
5. The category of machinery, electricity, and operation are represented with 1, 2, and 3. S_1 is the demand coefficient of machinery course (Category 1), S_2 and S_3 for electricity (Category 2), and operation (Category 3), respectively. This is a demand degree specified either by trainee, course scheduler or manager in charge of arranging training program. $0.0 \leqslant S_i \leqslant 1.0$ and $\sum_{i=1}^{3} S_i = 1.0$.

4.2. Constraints

1. Available training time

$$\sum_{i=1}^{m} G_i T_i \leqslant T \tag{2}$$

where T_i denotes the training time needed of course i; T is the total training time available for a trainee each time she or he takes a training section; and m is the number of courses.

2. Course importance requirement
Here W_i represents the importance level of course i. If W_i is limited to a specific value, for instance, greater than 0.5, that stands for courses with importance level higher than 0.5 will be solely arranged, thus the constraint is

$$W_i \geqslant 0.5 \tag{3}$$

3. Usage frequency requirement
Here F_i represents the frequency level of the course i. If F_i is limited to a specific value, for instance, greater than 0.4, then courses with frequency level higher than 0.4 will be exclusively arranged, thus:

$$F_i \geqslant 0.4 \tag{4}$$

4. Course level requirement
Here L_i denotes the level of course i. The course level is classified into three types: basic, moderate and advance level, hence L_i is 1, 2 or 3 respectively. For instance, to arrange courses with all levels, the constraint will set to:

$$L_i \geqslant 1 \tag{5}$$

5. Course for machine requirement
M_{ij} represents the membership value of course i to the machine type j. For instance, M_{12} is the membership value that course 1 related to machine type 2. $0.0 \leqslant M_{ij} \leqslant 1.0$, $i = 1,2,\ldots,m$, $k = 1,2,\ldots,p$. p is the

number of machine types, which is 2 in this study. If the Course for Machine value needs to be greater than 0.8 for machine type 2, then:

$$M_{i2} \geqslant 0.8 \quad (6)$$

6. Prerequisite course requirement

$$G_i G_j = 1, \quad i \neq j \quad (7)$$

This confines the prerequisite course to be arranged along with its corresponding course. For example, the course of "Ohm's Law" (G_9) is the prerequisite course of "Serial-parallel circuit" (G_8), then $G_9 G_8 = 1$.

7. Required course (RC) requirement
This fulfills some special training purposes, such as for novice training in a new position, some specific courses should be accomplished first. For instance:

$$G_1 = 1 \quad (8)$$

constrains the trainee to take the course of "Introduction to cutting tools".

4.3. Genetic algorithms for solution process

This research has considered the issue of the scheduling of the training course as an optimization problem. The objective function is set to meet demands from the trainee, such as training time and course level, etc. The model formulated in this study is a combinatorial model. The GA coding schema can be applied to the course scheduling. Utilizing GA enables solutions to be obtained promptly and easily because GA does not trap into the local optima and can reach a global solution. Moreover, GA employs multiple starting points to search for a solution simultaneously, speeding up the search process. The information represented by chromosome, in terms of GA, can be interchanged, decoded and computed to achieve better solution. According to the abovementioned reasons, GA was utilized as a solution tool in this research.

When arranging a training course, one major indicator is whether or not a specific course unit been picked as training unit. To build a model for course scheduling, the decision variables can be designed as a binary variable with 1 indicating course picked and 0 otherwise. Fig. 1 shows the bit presentation of course unit. Each box presents a course unit. The value in the box, 1 or 0, indicates its arrangement for a training program.

Many settings should be ascertained before GA is executed. In our illustrative model, variables were encoded into a chromosome, and a fitness function was built. A two-point crossover mechanism was used. The mutation rate was set to 0.01, while the crossover rate 0.8, with elitism selection. The initial population of the chromosome pool reaches 100, which is the empirical value for efficiently pursuing optimal solution. Other settings include: (1) total available training time 240 min; (2) the demand levels for course categories are: 0.5 for machinery, 0.4 for electricity, and 0.1 for operation; (3) if the optimal solution did not change over 50 generations, it stopped running. The GA process for course arrangement is shown in Fig. 2. The optimal solution found in the illustrative model is shown in Table 3.

Course Code	1	2	3	4	5	…	27	28	29	30
Bit Presentation	1	0	1	1	0	…	0	1	0	0

Fig. 1. Bit presentation of course unit.

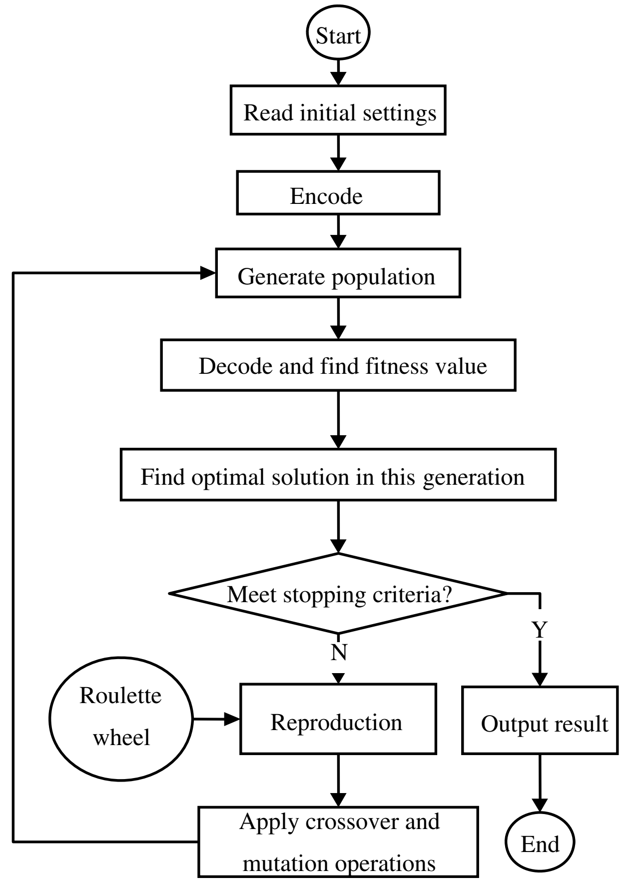

Fig. 2. Process of GA for course arrangement.

5. Computer assisted training system

5.1. Demand analysis

An optimization model was formulated to deal with training course scheduling for maintenance representatives in the machine tool sector. To build a computer assisted training system (CATS) by utilizing GA methodology, we first investigated the characteristics of training materials, and the practice of the training process. The demands from both trainees and course arrangers were then collected and analyzed. To analyze the functional demand of CATS, and to fully augment system usability, managers from six machine tool manufacturers were interviewed. All were managers working in the human resource departments of manufacturers ranked within the top 10 for sales figures

Table 3
The optimal curriculum combination

Code	Course title	Course category			Significance	Frequency	Level	Training time
		Machinery	Electricity	Operation				
1	Introduction to cutting tools	1.0	0.0	0.0	0.8	0.6	1	25
2	Introduction to robotics	1.0	0.0	0.0	0.6	0.5	3	20
4	Adjusting tool magazine	1.0	0.0	0.0	0.5	0.8	1	30
6	Trouble-shooting transmission box Type II	1.0	0.0	0.0	0.9	0.9	3	20
8	Serial and parallel circuit	0.0	1.0	0.0	0.9	0.5	1	20
9	Ohm's law	0.0	1.0	0.0	0.9	0.4	1	10
10	Stepping motor inspection	0.0	1.0	0.0	0.5	0.8	2	20
13	Repairing oil pump F-6801	0.8	0.2	0.0	0.6	0.4	3	25
17	Introduction to grasper driver (I)	0.0	1.0	0.0	0.5	0.7	2	15
18	Introduction to grasper driver (II)	0.0	1.0	0.0	0.6	0.9	2	15
25	Introduction to lubrication system	1.0	0.0	0.0	0.8	0.4	2	25
27	Repairing oil compressor	0.8	0.2	0.0	0.5	0.9	3	15

from 1999 to 2004 in Taiwan. They were Yeong-Ching Machinery, Yang Iron Works Co, Union Optronics Crop, Leadwell Taiwan, OR Taichung Machinery, and Chevalier Groups.

5.1.1. The machine tool sector

The machine tool industry is one of the most important industrial activities in Taiwan. Machine tool enterprises must have reliable operational ability to attract international orders in the highly competitive global environment. Five major characteristics of the machine tool industry were isolated from the interview materials.

1. The machine tool industry has critically close relations with the aerospace industry, electronics, the automobile industry and defense. It plays an important supportive and cooperative role with other industries.
2. The machine tool industry, which produces high-precision machine tools, is technology-intensive.
3. Demand for machine tools in market is dramatically influenced by economical cycles.
4. The numbers of components and range of materials is large. Enterprises frequently encounter urgent requests for changes of design.
5. While enterprises need to continuously invest on technology and human resources, the returns on investment are relatively low.

5.1.2. Essential elements of the interview

In-depth interviews were conducted to build up an information system for dealing with training course arrangement to solve most of the problems mentioned above. The major investigation was as follows: (1) basic information about the interviewed company, (2) the company situation with regard to computer and networking usage for employee training, (3) the present process and condition of employee training, and (4) the demand for CATS for maintenance personnel.

The interview conclusions were as follows: (1) the available time of the maintenance representative is limited; (2) the maintenance representatives should be better capable of handling all kinds of repair tasks; (3) no course scheduling mechanism was currently used; and (4) the industry urgently needs a CATS to handle course arrangement and to enhance training effectiveness. The interview material also uncovered many key factors and concerns for developing such a system. The operational practice, system analysis and system development are discussed in detail in the rest of this paper.

5.2. System analysis

The industry is not currently using CATSs to help train maintenance personnel, nor for further analysis of training information. The realization of the urgent need of the industry stimulated the development of a CATS. Developing a CATS is largely an attempt to foster effective employee training. With the aid of a CATS, the employee training will be completed more efficiently and effectively. This can help customers thus consequently promoting customer royalty and increasing customer satisfaction.

Before constructing the CATS, the operation of the training course arrangement for maintenance representatives should be investigated. According to Lin, Wu et al. (1998) and Lin, Hu, et al. (1998), course arrangement

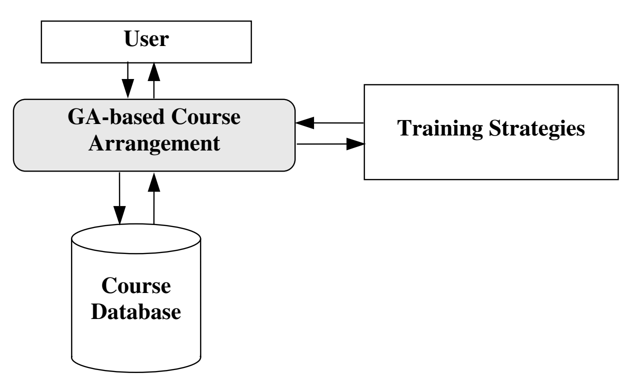

Fig. 3. System framework of CATS.

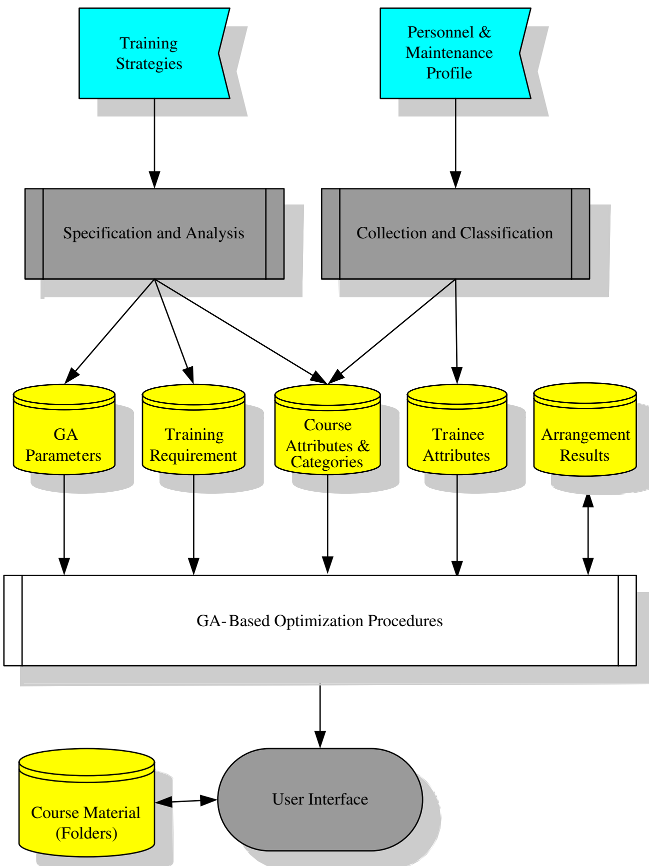

Fig. 4. Database structure of CATS.

management (CAM) system is a major subsystem for developing a computer managed instruction system in the machine tool sector. The authors also stated that the information of course arrangement is with reference to the course categories and importance of the training course. As a result, we developed and divided the CATS into four major modules, namely, user interface module, GA-based course arrangement module, training strategies module, and database management module, as illustrated in Fig. 3. General course arrangement for maintenance personnel in a CAM system are performed on the basis of the following requirements: (1) by demand and reactions of the customers, (2) by mission of the company, (3) by job functions or job responsibilities, (4) by newly released product, and (5) by individual needs.

5.3. System development

The prototype system was developed using many software packages: Access, Visual Basic, and Active Server Pages (ASP). Access was utilized to design the database. Visual Basic was used to construct the user interface. ASP facilitated connection of the system database and course materials, while integrating the whole system. The prototype of CATS is running on a web server with Windows operation system in a local machine tool manufacturer. After test activity and system refinement, the performance of the system is promising.

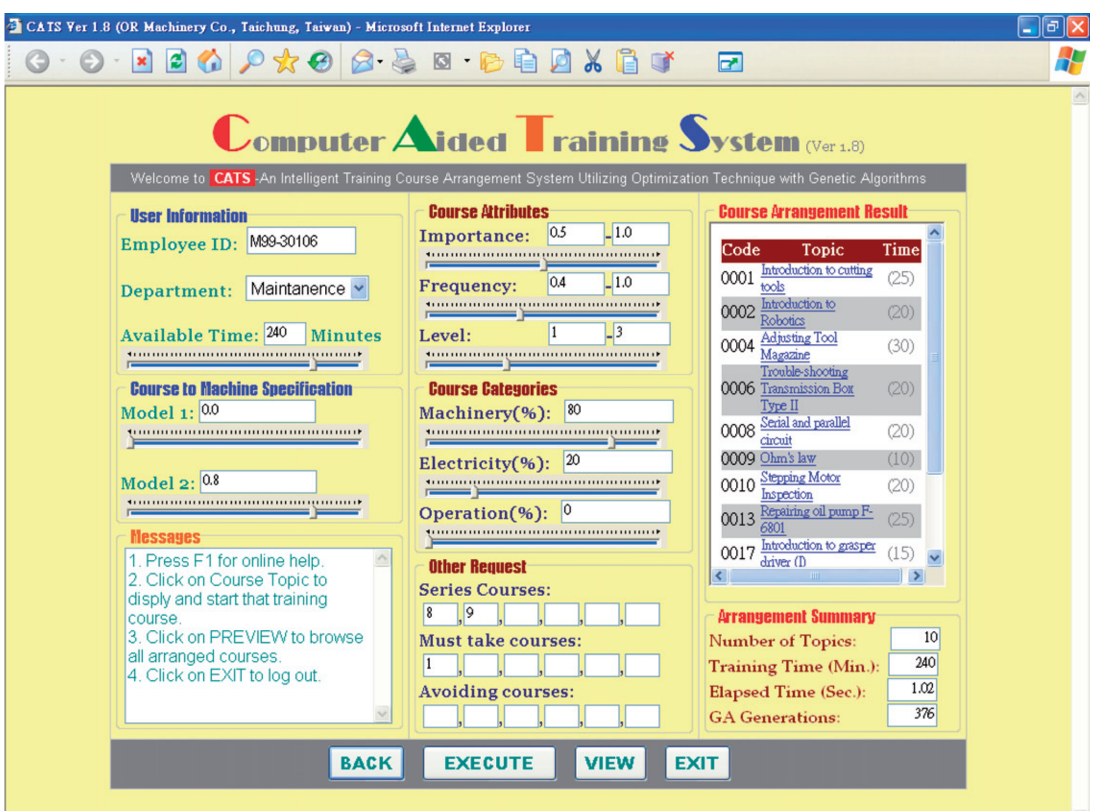

Fig. 5. Design of system interface.

5.3.1. Operation configuration

The CATS is configured for installation at the manufacturer's site with database applications installed. The system users are primarily maintenance personnel of the machine tool manufacturer. The CATS database is updated while the system receives commands from users or generates computational results. After executing the arrangement module, the system responds to the users with the list of arranged material, which users can view its content by activating an Internet browser.

5.3.2. Database design

The design of a database for the prototype system is mainly based on relational database with Access. The setting of primary keys and database normalization are inevitable for implementing a database application system successfully. The primary key is a field that uniquely describes each record. In the course arrangement management system, for instance, the course ID number is set to be the primary key in the data table storing course information. This field is unique and generated by the system automatically. There are five major tables used in the CATS, including trainee table, GA parameter table, course table, requirement table, and arrangement table. A file cabinet containing electronic course materials is also embedded in the CATS (Fig. 4).

5.3.3. Interface design

The system interface was designed considering system usability. It allows users to input data by simply sliding a number bar, making their choice from the list or key in numbers directly. Fig. 5 presents the design of system interface of the CATS. Since the CATS is a web-based application, it can operate with any Internet browser. The arranged courses are listed on the right part of the screen with total training time needed in minutes. Users of the system can click on title of the scheduled course to view the course material or click on view button to bring up the menu of all arranged courses and start the training section.

6. Conclusion

The main objective of this study is to construct an optimal course arrangement model, and to develop a prototype of CATS. We studied curriculum arrangement methods and framework in an adaptive training system. An optimal curriculum arrangement model with GA solution process is proposed. A CATS for maintenance representative training was developed to facilitate personnel training in the machine tool industry. With the building of the CATS, the training tasks of maintenance representatives in the machine tool industry become more effective and efficient. The scheduling time for a training section was shortened from several hours to 5 min with the aid of the CATS. The effectiveness was reported by system user as satisfactory and promising. In short, the significance of this research is as follows: (1) investigating the characteristics of employee training of maintenance representatives and the characteristics of training course, (2) constructing optimal course arrangement model with Genetic Algorithms as rapid solution procedures, and (3) developing a computer aided training system with the ability of training planning, execution, and management.

As for the continuation of the exploitable and extendable part of this study, we are seeking ways to improve some features of the CATS: (1) The course attribute value is not easy to determine. Methods to set appropriate course attribute value deserve in-depth investigation. (2) Each trainee has a different background and knowledge level, and the ability to absorb knowledge from different types of presentation is also different. Therefore, adjusting the attribute values of each course according to each unique trainee might help increase training effectiveness. (3) The complete and solid design of course materials is necessary in the CATS. Companies adapting the CATS with rigid course materials will increase training performance.

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