György Bicsák

GENETIC ALGORITHM BASED TIME SCHEDULE MANAGEMENT FOR SMALL AEROSPACE COMPANIES

Time schedule management is a really up-to-date problem considering the opposite interests of the employers and employees in the working hours. In order to maximize the profit employers are tended to overload their workers, which leads to exhaustion and because of that profit reduction. In the case of smaller aerospace companies, where the employees have to work not only in a specified area but they are involved in more than one projects, and additionally the company has to meet with more and stricter demands and rules, the time scheduling often becomes a number one priority. The scheduling is usually done manually taking several days or weeks of iterative repair after the feedback from the employees. The scope of this paper is to investigate a genetic algorithm (GA) for time schedule management purposes for a small, Part-147 organization: to investigate the environment, and influencing constraints, objectives.

Keywords: *genetic algorithm, time schedule management, Part-147, SWOT analysis*

INTRODUCTION

As technology continuously develops, time has been becoming the highest priority from all the respected management parameters. In the global stock market dollar millions can be earned or lost in nanoseconds by applying stock-optimizing algorithms software with high-performance computers.

Time management has already a wide-range of appliance, and several approaches. According to the Pareto Principle (or usually known as 80-20 rule), the vast majority of impact in anything comes from a small proportion of activities, people or effort, and focuses on the 20% of the activities or tasks are most important. The Pickle Jar Theory states that the more important tasks have to be done at first, and the less important work can be done in the spaces between and after a major project or tasks. Maslow’s Theory focuses on the higher goals of fulfilment, spirituality and well-being. It assumes that in the interests of greater efficiency sacrificing bigger things, like satisfaction, then it is a moot victory. These general time-management methods have got implementations in particular fields from everyday usage, up to schedule management processes in large, international companies.

But aerospace industry requires more specific solutions generally. Recently, the breakthrough innovations and leading technologies [16] or intelligent systems [12] are usually appears in the aerospace industry despite the strict regulations.

More and more problems are solved with different kind of optimization methods from the aerodynamic design or dynamic mathematic model build-up problems [3], through the inverse design problems [18], to the process-management optimization problems, but most of these methods are subject to several undesirable restrictions. [15] These methods require the knowledge derivatives of the given particular field for each parameter, or combination of parameters for higher order of coupling. To evolve a particular solution for a given problem can demand significant man-hour, which is not affordable for smaller companies, meanwhile at larger organizations whole departments can deal with the problem. So smaller companies require smarter, more cost-efficient solutions, which are also capable to reduce the workload of the employees. [4]

Specific Demands of a Part-147 Training Organization

The operation of a PART-147 Maintenance Training Organization is strictly determined by numerous regulations and laws, like European Aviation Safety Agency (EASA), or the European Aviation Authorities (EU NAA). The operational requirements are defined by the EASA Annex IV (Part-147) for approved training organizations which conduct training and testing of certifying staff. The knowledge of specific subject modules in accordance with Appendix I must be proven by examinations. In accordance with EASA Part-145 the Aircraft Maintenance Licence (AML) can be issued after a defined period of experience in a maintenance organisation. This time interval can be reduced if the applicant participates in an approved training course, organized by a Part-147 company, which is capable to guarantee this minimum standard in theoretical and practical training.

The main functions/duties of a Part-147 organization:

- Managing and maintaining an adequate facility which must include appropriate facilities for the use of training courses, and securely storing of assessment papers, completed students answer papers, and every related document.
- Maintaining, monitoring, and auditing the Training Material and Question Bank
- Maintain and Manage an Archive
- Ensure a professional staff with appropriate qualifications, organize necessary self-development trainings in order to maintain or upgrade the instructors competence
- Organize different training courses (type training, continuation training, other trainings)

Of course additional operative tasks have to be also handled. These wide range of duties, especially at a small company, such as AEROK Ltd. where the total staff number is only 9, the organization of these tasks is a daily problem which calls for novel, innovative ideas. The article is scoped to investigate a possibility to one of the biggest challenges of the company: automatizing the time-scheduling management processes with applying genetic algorithm methods.

GENETIC ALGORITHM FUNDAMENTALS

General Algorithm (GA) is a relatively new solution tool for optimization problems in a really wide range. The method is inspired by the genetic processes of biological organisms, and the evolution itself. The natural selection and “survival of the fittest” can be observed in these organisms, over many generations and populations, firstly stated by Charles Darwin in “The Origin of Species”. By implementing this process, the GAs are able to “evolve” solutions of the real world problems, and lately of different engineering problems, if the coding is suitable. [5]

The fundamentals and basic principles of GAs have been laid down by John Holland in 1975 [11]. The processes which are essential to evolution are simulated by GAs in natural populations. GAs are relatively young algorithms, therefore it is strictly determined which biological processes are essential for evolution and which processes have less or no role.

Individuals in the nature compete with each other for food, water or shelter, in short for resources. Furthermore the members of the same species often compete to attract a mate. The most successful individuals in surviving and attracting mates will have a relatively larger numbers of offspring, meanwhile poorly performing individuals have chance to produce less, or even no spring at all. Because of this pattern the highly adapted, or generally called "fit" individuals' genes are spreading to an increasing number in each successive generation. "Superfit" offspring can be produced by the combination of good characteristics from different ancestors, whose fitness is even greater than either of the parents. Of course, this process is resulted in species evolving to become more suited to their environment from generation to generation. [5]

The motor of the evolution of the species is the random mutation: the mutation of the species' genetic code can resulted in better or worse springs.

The GAs use the same algorithm, but the best solution is searched during the process with using the same considerations, while in nature the living conditions are changing continuously. The GAs are built up from the following main steps: [1]

1. Initialization: the algorithm sets up the possible solutions; determines the population
2. Evaluation: the algorithm calculates the fitness function, and the fitness of the given population
3. Selection: from the actual solutions the algorithm selects two parents according to their fitness (there are numerous selection schemes, but generally the better the fitness, the bigger chance to be selected)
4. Crossover: the parents are crossed with a crossover possibility to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents
5. Mutation: new offspring is mutated at each position in chromosome with a mutation probability.
6. Reproduction: The new offspring takes the parents place in the new population; the population is upgraded.
7. Termination criteria: If the termination criteria is satisfied, the algorithm is stopped, and the best solution is the current population.
8. End of process.

The process is illustrated by Figure 1.

One of the biggest challenge is to determine the genetic code, which involves the description of possible solutions, the initial population. At the same time the evaluation criteria have to be specified. Finally, the parameters of the algorithm, even those which are selected heuristically, have to be determined, like the size of the population, reproduction rate, mutation rate. After all the initial population can be created automatically. [2]

Two basic types of genetic algorithms are known depending on whether they are searching the better solutions in genotype or phenotype level. The genotype is the sum of the stored information in the genes, which determines the species outlook, or called phenotype. In programming level this means that the decoding function has to be well determined. [2]

The GA generates the phenotypes from the possibilities described in genotype space, which can be imagined as a super-structure, or as individual species. After evaluating each species, the evaluation space can be determined, and then the GA fitness space can be derived, as it is illustrated in Figure 2. [2]

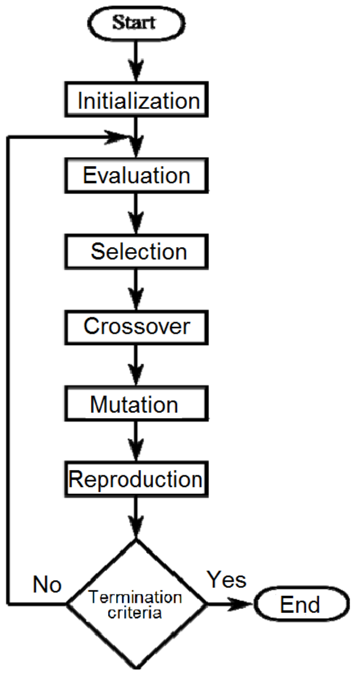

Figure 1. The genetic algorithm flowchart

The main advantage of GAs that by their nature, they lend themselves to parallel-execution, which provides a significantly faster optimization process. However, parallelizing the code used for evaluation is still a challenge.

According to their power and flexibility, their application is possible at a wide and ever growing range of optimization problems. The solution method allows to find globally competitive optima in large and complex search spaces. Furthermore, even a “standard” genetic algorithm is able to handle such problems, which cannot be solved with traditional optimization methods, such as: [6]

- discrete spaces
- nonlinear, discontinuous evaluation functions
- nonlinear, discontinuous constraints.

This capability makes possible for GAs to be applied to a different scheduling applications in a wide variety of domains like:

- supply chain management,
- shop/flow scheduling [7]
- class/timetable scheduling, [10]
- urban transit system,
- logistic delivery system,
- crew scheduling,
- exam scheduling, [17]
- training organization, optimization
- project management, scheduling…

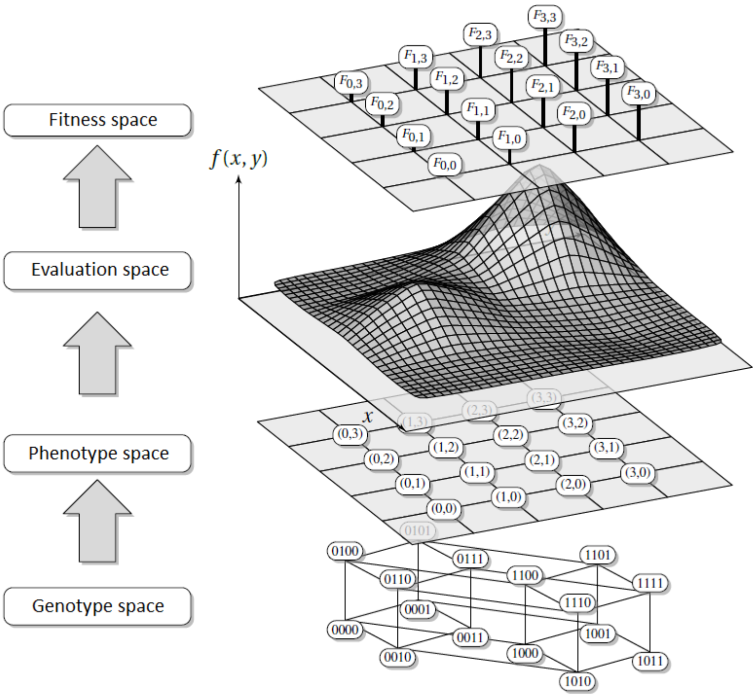

Figure 2. The different spaces (genotype, phenotype, evaluation and fitness) of a genetic algorithm and their connection [2]

Disadvantages

Especially if the crossover operator does not maintain genetic material, the population will not improve and the genetic algorithm will perform no better than a random search. Sometimes, the result is not mathematically correct, or the algorithm is not even converging. Another disadvantage that local peaks should be avoided in the fitness landscape, but sometimes the method stucks at one instead of the global optima. [14]

In the following, the necessary initial steps are investigated for a special implementation of the genetic algorithms for a small Par-147 training organization time-schedule problem.

DETERMINATION OF THE INFLUENCING PARAMETERS AND THE INVESTIGATED PROBLEM

The scope of the recent paper is to investigate the constraints of a time-scheduling method for a small Part-147 organization, in order to find the optimal initial date for a new training course, and to make the scheduling process automatic. It is essential to specify the constraints, because they determine the inlet boundary conditions and outcomes of the method, furthermore are defining the feasibility of a schedule. The objectives define the optimality of a schedule. The main difference between them is that constraints must be satisfied, while objectives should be satisfied. [13] With other terms, constraints are usually called as hard constraints, and objectives are referred as light constraints. [9]

Two types of outcomes can be received: those which satisfy the hard constraints are the feasible solutions, those which satisfy not only the hard constraints but the light constraints also, are the optimal schedule. [8] The problematic part is to determine the objective measures, which indicate the goodness/fitness of a schedule. In the case of project scheduling problems the goal is to minimize the duration of the project, which seems reasonable for this particular case, when the duration of a training course should be as short as it is possible.

The other difficulty is the objectives' conflict. For example is it practical to schedule one instructor for whole day, because then the students' attention is not split, but teaching 7 hours straight is really stressful, thus the performance of the instructor can decay, so it is also reasonable to divide one work day between two instructors. Multiple objectives require a mechanism for defining the relationship between conflicting objectives in order according to the priorities of the company. [13]

Finally, the optimal solution has to provide a back-up plan, for example if an instructor is ill, or is somehow not available. If the optimal scheduling consists only one realization possibility, the first disturbance will crush the timetable, and only the manual intervention can handle the situation. Even better, if the algorithm operates in real-time: meaning of any disturbance occurs, the algorithm can find another good solution automatically.

Hard constraints

The hard constraints are responsible to investigate whether the given solution is feasible and acceptable. The actual population, and the particular solution have to fit into these type of constraints. The hard constraints are determined by the time (we are not able to teach 25 hours a day, however it would be great), laws, regulations, the instructed training material and the exams. According to this, the following hard constraints have to be taken into consideration:

- **Work day**: One day can contain maximum 7 training hours (1 hour contains 50 minutes of class and 10 minutes of break). Minimum training hours are not determined, but the closer minimum hours to 7, the better the solution.
- **Work week**: One work week contains 5 work days, but in special circumstances Saturday can be also used, thus a work week can be 6 days long. At least 1 rest day has to be provided for the participants.
- **Duration**: The number of lessons are determined for each training course, it can't be lower or higher.
- **Holidays**: Lessons can't be planned on holidays.
- **Training program**: The training program (in agreement with the Training Need Analysis) contains each instructed ATA chapter, and their hour requirement.
- **Exams**: One exam per week has to be scheduled in order to avoid the piling of the training material. The length of the exam is determined by the involved chapters, but practically 2 hours length is recommended.
- **Training material structure**: The order of some lectures are determined, like the course has to be started with "General description".
- **Lecture length**: The length of each instructed ATA chapter is determined, and can't be changed.
- **Availability of the instructors**: Depending on their activity, in some particular time-intervals they are not available.
- **Inherence of lectures**: If an ATA chapter has started, it has to be finished within one week.

Light constraints

These type of constraints should be realized, but they don't have to be. Generally the light constraints are rated with penalty points, and the goal is to minimize the penalty points. The optimal solution is found, when the sum of the penalty points are zero. But considering that how much light constraints have effect on the time-scheduling, it is almost impossible to completely eliminate these penalty points. The following light constraints have to be taken into consideration:

- **Exam scheduling**: An exam should be scheduled in the morning, for better performance. The only exception is the last exam.
- **Daily inherence of lectures**: It is preferred to schedule one ATA chapter to one day, and if it is possible not divide them (for example if an ATA chapter requires 5 hours, it shouldn't be separated to two days)
- **Single class avoidance**: It should be avoided to schedule a single class for a day, if the given ATA chapter is longer than one hour.
- **Pre-requirements**: Some of the ATA chapters requires the knowledge of other ATA chapters. During the scheduling these pre-requirements should be taken into consideration.
- **Requests of instructors**: Some instructors prefers forenoon, or afternoon lectures.
- **Training start and finish time**: The elapsed time between the start and finish of a training course should be minimized, sith the participating maintenance personnel have to minimize the loss of work time.
- **Instructor accommodation cost**: In the case of a training course organized abroad, the accommodation costs should be minimized.
- **Instructor travel cost**: In the case of a training course organized abroad, the travel costs should be minimized.

Goodness/Fitness

The goodness or fitness of a scheduling has to be inspected. Of course the hard constraints have to be satisfied, if a schedule does not fit, then it is not a feasible solution. The penalty points of the lights constraints determines actually the goodness of a solution, the higher the sum of the penalty points, the worse the schedule. The main goal is to minimize the elapsed time between the start and finish date of a training course. Besides the price of a course, the time demand is the second most important factor, which determines how much participants want to attend. The time, maintenance personnel spends in course is a work time, which is maximized, or even denied in special parts of the year (like near to peak season).

Besides the competitiveness the operational costs have to be minimized, especially when a course is organized abroad. In that case the company has to solve the travelling and accommodation of the instructors, thus in that case it is not suitable to separate the ATA chapters to different weeks or even days, which are taught by the same instructor. By setting constant costs both for travelling and for the accommodation these parameters can be taken into consideration. It is also solvable to automatize the cost-calculation by integrating online databases, web pages; but the invested costs probably wouldn't be remuneratory.

The advantage of this method is that is can be designed to operate in real-time mode; meaning if the training schedule has to be changed because of any unforeseeable event, the algorithm would be able to reschedule the lecture automatically, alert the instructors or even participants by using Microsoft Office macros or Google applications.

Conclusions, further plans

After investigating the problem, the environment, and influencing parameters, the followings can be concluded: the genetic algorithm provide a novel approach for time-scheduling from the viewpoint of a small Part-147 organization. The summarization of the topic is included in the following SWOT analysis (see Figure 3), which illustrates the strengths, weaknesses, opportunities, threats of the topic.

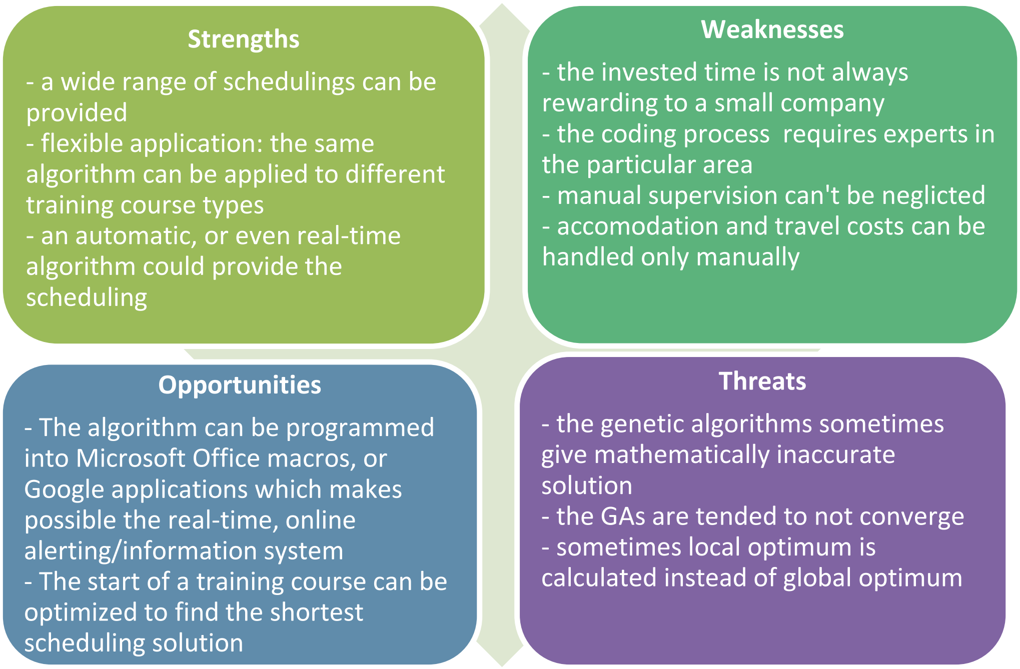

Figure 3. SWOT analysis of applying genetic algorithms for a Part-147 organization time-scheduling management processes

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GENETIKUS ALGORITMUS ALAPÚ IDŐBEOSZTÁS-MENEDZSMENT KIS REPÜLŐIPARI CÉGEKNEK

Az időbeosztás-menedzsment egy olyan aktuális probléma, melynek megoldását folytonosan nehezíti a munkáltatók és munkavállalók ellentétes érdeke a dolgozott órák tekintetében. A profit maximalizálásának érdekében a munkáltatók mindig megpróbálják több és több munkára bízni a beosztottakat, mely viszont kimerültséghez vezet, mely ~~a~~ pont a profit csökkenését eredményezi. Kisebb repülőipari cégeknél, ahol egy-egy munkavállalónak ráadásul nem csak egy adott szakterülettel kell foglalkoznia, hanem általában több, egymástól eltérő projecten is, a cégnek magának ráadásul sokkal szigorúbb feltételeknek kell megfelelnie, mint a gazdasági szektor más területein. Így az időbeosztás menedzsment igen nagy prioritással rendelkezik. Általában az időbeosztások manuálisan, több napos munkával, és utólagos korrekcióval készülnek el. Ezen cikk célja egy genetikus algoritmusra épülő, automatikus időbeosztó rendszer koncepcionális vizsgálatának elvégzése, mely lehetővé teszi egy Part-147-es szervezet automatikus tanfolyami beosztásának elkészítését.

Kulcsszavak: *genetikus algoritmus, időbeosztás management, Part-147, SWOT analízis*

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