AN ADAPTABLE COMPUTATIONAL MODEL FOR SCHEDULING TRAINING SESSIONS

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KEYWORDS

Scheduling, School Timetabling, Genetic Algorithms, Neural Networks

ABSTRACT

Human resources management is a significant item of many kinds of activities, and it commonly involves various scheduling events. In terms of computational complexity, scheduling is a highly constrained combinatorial problem, which is often being solved by evolutionary techniques, such as genetic algorithms (GA). Human resource planning is often characterized by a great extent of human factor to be considered, so it could turn out hard for it to be reduced to a constraint satisfaction problem. For solving such problems the paper proposes the GA model reinforced by neural networks in order to provide GA with an adaptable rating procedure. As a case of scheduling, school timetabling has been analyzed to demonstrate the idea. The computer system using the proposed model is still being developed, and the goal of the paper is to describe the new methodology.

1 TIMETABLING PROBLEM

The timetabling problem is a highly constrained combinatorial problem and has an NP-complete degree of complexity (Arous et al. 1999). Various kinds of timetabling problems differ in terms of constraints to be observed and objectives involved. For instance, the timetabling in schools may differ a lot of the one in universities. This paper deals with school timetabling as a case of scheduling.

In general scheduling problem, events must be arranged around a set of time slots, so as to satisfy a number of constraints and optimize a set of objectives. Events to be arranged are lessons. Resources, to be referred by constraints and objectives are groups of trainees (groups), teachers and classrooms (rooms).

There are two types of constraints – *hard* and *soft* (Fernandes et al. 1999), (Tam et al. 2003).
Hard constraints:

- A group, a teacher, or a room cannot be assigned to more than one lesson in the same time slot,
- A group, a teacher or a room cannot be assigned to a time slot if a predefined unavailability exists,
- The assigned room should be large enough for the group,
- The assigned room should contain all features necessary for the lesson.

A few of soft constraints:

- Avoid gaps as much as possible,
- Arrange lessons uniformly over the days of week,
- Observe limitations on faculties of teachers and trainees,
- Observe predefined recommendations as much as possible,
- Balance the layout of lessons in terms of themes (subjects),
- Some lessons need more then one period in turn.

In timetabling of training sessions, especially in school timetabling, an important problem is the *human factor* involved, e.g. thematic arrangement of lessons according mental faculties of trainees. It makes constraints hard to define and even hard to recognize, so it becomes more difficult to obtain really usable timetables.

2 GENETIC ALGORITHMS – MEANS OF SOLVING OPTIMIZATION PROBLEMS

To solve optimization problems like timetabling problem, GA are often been applied (Arous et al. 1999), (Fernandes et al. 1999). GA (see Figure 1) exploit principles of evolutionary biology, including such biology-originated techniques as inheritance, mutation, natural selection, and recombination.

A population is a main object dealt by GA. It consists of individuals, which are being improved during evolutionary process. When solving optimization problems by GA, the single solutions are regarded as individuals. The operation of a GA is a cyclic process, which resembles alternation of generations in biological systems.

An important requirement for the problem domain using GA, is a possibility to evaluate (rate) solutions at any phase of the evolutionary process. The rating is done by the *fitness function*.

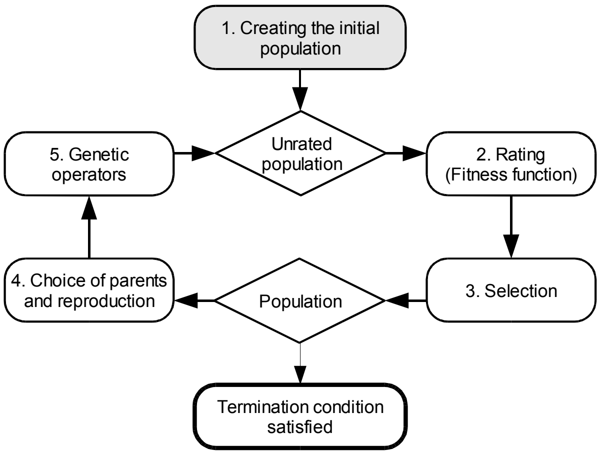

Figure 1. The general schema for genetic algorithms

3 GENETIC ALGORITHMS TO SOLVE SCHOOL TIMETABLING PROBLEM

The school timetabling is a specific problem in the respect that constraints are divided into hard and soft ones.

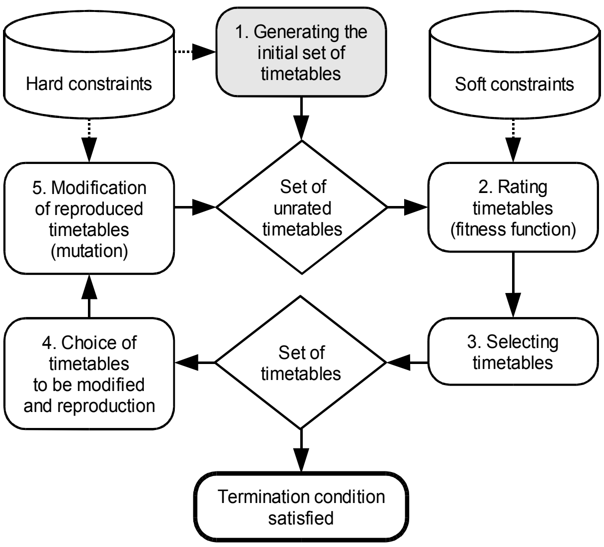

Figure 2. The schema for genetic algorithms in timetabling

Thus a logical way is to separate the use of both categories of constraints within GA (see Figure 2):

- Application of hard constraints is carried out at the phases of initial generation and modification, thereby ensuring the algorithm to operate just valid timetables,
- Timetables are being rated according soft constraints only.

GA themselves do not use specific timetable knowledge when it exists. The way out is using heuristics at various phases, especially at the modification phase to determine the type of modification and amount of solutions (timetables) involved. Applying soft constraints at the modification phase could substantially improve upon GA. Yet another specific character of timetabling with GA is mutation as the only genetic operator available.

4 REINFORCING GENETIC ALGORITHMS BY NEURAL NETWORKS

4.1 GENERAL SUGGESTIONS

One of the most complicated items to implement GA is providing with the rating procedure, i.e. creating the *fitness function*. It's hard to evaluate various conditions, and it's still harder to even define the rating criteria.

Observation. The layout of subjects scheduled is of great importance in schools.
Unlike universities schools have to observe the correct distribution of subjects over the learning period considering mental faculties and psychological features of schoolchildren.

Observation. Ready-made school timetables represent useful knowledge for timetabling process.
In general, ready-made school timetables provide significant information on layout of subjects in timetable. Considerably less information can be obtained on teachers and classrooms. That's because of differences among schools on teachers and classrooms available, whereas the information on subjects is considered to be usable, since various schools keep similar sets of subjects. Having explored available data on timetables in many schools has made such considerations.

Proposal. Make use of subject information of ready-made school timetables to rate timetables within GA.
Since school timetabling is characterized by having human factor involved to a comparatively great extent, the proposal is to use neural networks as the information base (see Figure 3). By the mentioned approach the ready-made school timetables are regarded as "the positive practice", and the fitness is defined as resemblance to them.
Application of artificial neural networks to support decision-taking processes is known with similar problems. E.g., (Alifantis et al. 2001) describes a methodology of using neural networks to develop job-scheduling advisor. Unfortunately, without solid experimental work done, it's impossible to make out the extent of neural networks to be able to extract essential features from existing timetables. There are just

suggestions based on experience in solving another problems.

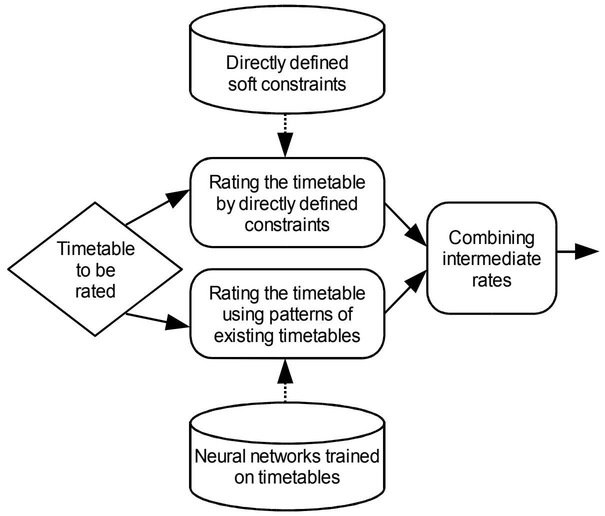

Figure 3. The timetable-rating block as a part of genetic algorithm

4.2 ARTIFICIAL NEURAL NETWORKS

Artificial neural networks represent a set of computational models made with a certain resemblance to the human brain. Work on artificial neural networks has been motivated by recognition that the human brain computes in an entirely different way from the conventional digital computer. The brain is highly complex, nonlinear, and parallel information-processing system. The brain has a great structure and the ability to build up its own rules through the experience. (Haykin 1999)

In its most general form, a neural network is a machine that is designed to model the way in which the brain performs a particular task or function of interest (Haykin 1999). To be even shorter, a neural network is a model of the human brain. However, to compare to the human brain a neural network is regarded to be very simplified, resembling the brain in two respects:

- Knowledge is acquired by the network from its environment through a learning process;
- Interneuron connection strengths, known as synaptic weights, are used to store the acquired knowledge.

A single neuron is a quite simple computing unit; nevertheless a certain quantity of connected neurons can perform complex tasks. Neurons are approximately six orders of magnitude slower then today's digital processors. However, the enormous potential of the brain is reached by approximately 10 billion neurons and 60 trillion interconnections between them.

4.3 REPRESENTATION OF A TIMETABLE

Timetable is defined as a set of timetables of separate classes. $U = \{A_1, A_2, ..., A_c\}$, where A_x represent the timetable of the group x.
The week timetable of a fixed class is represented by a vector of elements $A_x = [a_{11}, a_{12}, ..., a_{1h}, a_{21}, ..., a_{dh}]$, where a_{ij} represents a lesson or lessons for the class of the day i and period j.
In the simplest case there are no parallel lessons for the class, so in terms of subjects – a_{ij} can be coded as one subject. However in general there can be parallel lessons, so a_{ij} is to be coded as a set of subjects.

Observation. Subjects can be categorized according the themes comprised, and doing this will bring useful additional information on timetables.

Observation. To evaluate the timetable style in terms of subjects' layout, there might be enough with less detailed information as subjects – *subject types*.
This observation can be exemplified by the following soft constraint: Avoid assigning to many lessons of hard sciences in turn.

Proposal. Any timetable element a_{ij} can be coded as a set of subject types.

4.4 CONSTRUCTING THE NEURAL BLOCK FOR TIMETABLE RATING

Various schools have got different sets of classes – there are primary schools and secondary schools, and there are schools with parallel classes and without them. It makes constructing a single neural network to rate a whole timetable practically impossible.

Proposal. Construct several neural networks – one for each grade (see Figure 4). So the neural block for rating timetables will consist of 12 separate networks $F_1, F_2, ..., F_{12}$.
Layout of subject types represent timetables stored in the neural block.
To rate a timetable U, the neural block performs following steps:

- The appropriate neural network F_y is rating each timetable of a separate class A_x. Thereby we obtain separate ratings for each class $r_1, r_2, ..., r_c$.
- Obtained ratings are combined together in a certain manner to make out the total rating of the timetable.

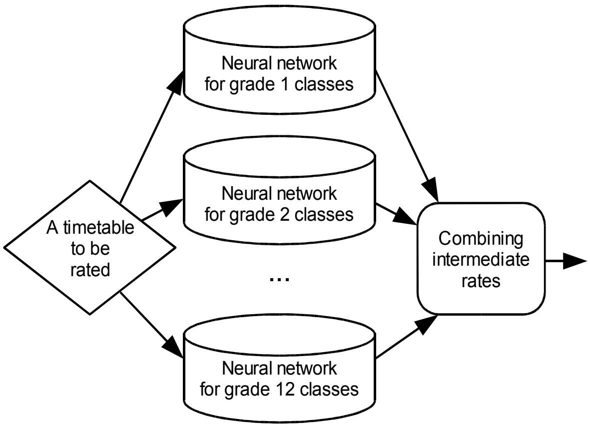

Figure 4. The neural block for rating timetables

4.5 CHOOSING THE NEURAL MODEL

Neural network is a computational model that acquires ability to function through a learning process. The goal of each neural network in the neural block is to rate one piece of the whole timetable. The model should be chosen according the problem to be solved and the data available.

The following features of the problem domain will impact into choice of the neural model:

- The set of available timetable patterns consists of valid and practically utilized ones, i.e. representatives of "the positive practice", but we have no patterns representing invalid or not so good timetables. Thus a pure model of perceptron rather wouldn't suit. For the perceptron a uniformly distributed set of training patterns is required to ensure the necessary performance.
- The output of the rating function is a value with a lot of possible degrees, not just "valid" or "invalid". Considering that, a pure model of Kohonen network wouldn't suit as well.

A hybrid model of perceptron and Kohonen models seems to be able to help solving the problem

5 CONCLUSION

Since ready-made timetables contain a lot of information about the manner timetables are built, there's a reason to believe that incorporating neural networks into timetabling system will improve upon pure model of genetic algorithms.

The proposed model is characterized by a high specialization, and it isn't a universal means to solve scheduling problems. The model is being designed with the emphasis on practical usability considering the human factor.

Althogh the proposed model seems to be very specific and available just in particular cases (here – school timetabling), it demonstrates a new approach – the adaptability of a model. This idea could be useful solving other optimization problems even if to be applied in a different, problem specific manner.

A substantial experimental work is required to construct and configure a block of neural networks to be able to properly extract features from timetable patterns. The computer system based on the proposed model is being implemented.

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BIOGRAPHY

Jānis Zuters has graduated from the University of Latvia Department of Compter Science in 1999 (Mg. sc. comp.) and now is a doctoral student here. He is a lecturer of information technologies at the University of Latvia and at the Vidzeme University College. The main field of his researches is Artificial Neural Networks.