Genetic Algorithms: A New Approach to the Timetable Problem

Alberto Colorni, Marco Dorigo and Vittorio Maniezzo *

In this paper we present the results of a research relative to the ascertainment of limits and potentials of genetic algorithms [4, 3, 6] in addressing highly constrained optimization problems, where a minimal change to a feasible solution is very likely to yield an infeasible one. As a test problem, we have chosen the timetable problem (TTP), a problem that is known to be NP-hard [5], which has been intensively investigated for its practical relevance [2, 1].

The problem instance we faced was the construction of a class timetable for an Italian highschool. The problem may be decomposed into formulation of several interrelated timetables, one for each pair of sections of the school considered. A pair of sections can be in fact processed as an "atomic unit," not further decomposable given its high internal dependencies, but relatively isolated from the other pairs of sections.

Given these premises, the problem is described by:

- a list of the teachers of the pair of sections (20 in our case),
- a list of the classes involved (10 for the pair of sections),
- a list of the weekly teaching hours for each class(30),
- a curriculum of each class, that is the list of the frequencies of the teachers working in that class,
- some external conditions, for example the hours that the teachers use to teach in other sections.

The formal representation of the TTP is as follows: given the 5-tuple$< H, T, A, R, f >$ where

T is a finite set $\{T_1, T_2, \ldots, T_i, \ldots, T_m\}$ of resources (teachers),

*Politecnico di Milano, Dipartimento di Elettronica, Milano, Italy.

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H is a finite set $\{H_1, H_2, \ldots, H_j, \ldots, H_n\}$ of time intervals (hours),

A is a set of jobs to be accomplished (lessons to be taught),

R is an $m * n$ matrix of $r_{ij} \in A$ (a time table),

f is an objective function to be maximized, $f : R \rightarrow I\!R$,

We want to compute $\max f(\sigma, \Delta, \Omega, \Pi)$ where

σ is the number of superimposition, that is the situations where more that one teacher is present in the same class at the same time. (this is controlled by a parameter that may be different than zero for reasons of efficiency),

Δ is the set of didactic goals (e.g., having the hours of the same subject spread over the whole week),

Ω is a set of organizational goals (e.g., for each hour of the week having two teachers available for possible temporary teaching posts),

Π is a set of personal goals (such as for each teacher to have a class-free day).

Every solution (timetable) generated by our algorithm is feasible if it satisfies the following constraints:

- Every teacher and every class must be present in the timetable in a predefined number of hours.
- There may not be more than one teacher in the same class in the same hour.
- No teacher can be present in two different classes in the same hour.
- There is no "uncovered hours" (that is, hours when no teacher has been assigned to a class).

The approach we followed for the solution of this problem is the following. We decided to choose as the alphabet, the set A of the jobs that the teachers have to perform whose elements include the lessons to be taught and other activities. This alphabet allows us to represent the problem as a matrix R (an $m * n$ matrix of $r_{ij} \in A$) where each row corresponds to a teacher and each column to an hour. Every element r_{ij} of the matrix R is a gene: its allelic value may vary on the subset of A specific to the teacher corresponding to the row containing the gene. The constraints are managed as follows: