EVOLUTIONARY STRATEGIES FOR THE ACADEMIC CURRICULUM BALANCED PROBLEM

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Keywords: Evolutionary strategies, Academic curriculum balanced problem.

Abstract: The Balanced Academic Curriculum Problem (BACP) is considered an optimization problem, which consist in the assignment of courses in periods that form an academic curriculum so that the prerequisites are satisfied and the courses load is balanced for students. The BACP is a constraint satisfaction problem classified as NP- Hard. In this paper we present the solution to a modified problem BACP where the loads can be the equals or different for each one of the periods and is allowed to have some courses in a specific period. This problem is modeled as an integer programming problem, for which had been obtained solutions for some of their instances with HyperLingo but not for all. Therefore, we propose the use of evolutionary strategies for its solution. The results obtained for the instances of the modified and the original BACP, proposed in the CSPLib, showing that with the use of evolutionary strategies is possible to find the solution for instances of the problem that with the formal method is not possible to find.

1 INTRODUCTION

A curriculum is formed by a set of courses, these courses have assigned a number of credits that represent the effort in hours per week that the student requires to follow the courses successfully, for parents or tutors and the institution represents the economic cost of this course. The academic load is the sum of the credits of the courses in a given period.

Therefore correct planning of the curriculum, result in benefit of the institution and all the involved: To the institutions favors the departmentalization and the resulting cost savings, to students in a good load distribution because this represents the academic effort that they require invest, the parent or tutors a good distribution of the credits allow planning financial efforts.

Balanced Academic Curriculum Program (BACP) consists in to assign courses to the periods that are part of curriculum so that prerequisites are satisfied and the credits load is balanced. The BACP problem belongs to the class of problems CSP (Constraint Satisfaction Problems), as this is a decisional optimization problem is classified as NP-Hard (Salazar, 2001).

The BACP problem was introduced by Castro and Manzano (Castro, 2001) with three test cases called BACP8, BACP10 and BACP12 included in CSPLib and they have been used to test models proposed by other researchers.

The model proposed by Castro and Manzano uses the following integer programming model:

Parameters

m : Number of courses
n : Number of periods
α_i : Number of course credits i; $\forall i = 1, \ldots, m$
β : Minimum academic load per period
γ : Maximum academic load per period
δ : Minimum amount of courses per period
ε : Maximum amount of courses per period

Decision Variables

x_i : period of course i, $\forall i = 1, \ldots, m$, $x_i \in [1,\ldots,n]$
c_i : load academic of course i, $\forall i = 1, \ldots, m$

Objective Function

$$Min \quad c = Max(\sum_{k=1}^{m} c_k \mid x_k = j, \forall j = 1,..n) \qquad (1)$$

V. Rosas-Tellez L., L. Martínez-Flores J. and Zanella-Palacios V..
EVOLUTIONARY STRATEGIES FOR THE ACADEMIC CURRICULUM BALANCED PROBLEM.
DOI: 10.5220/0003723805340538
In *Proceedings of the International Conference on Evolutionary Computation Theory and Applications* (FEC-2011), pages 534-538
ISBN: 978-989-8425-83-6

Constraints
If the course b has the course a as prerequisite then:
$x_a < x_b$

$$\beta \leq \sum_{k=1}^{m} c_k \quad | \; x_k = j \leq \gamma \tag{2}$$

$$\delta \leq \sum_{k=1}^{m} 1 \; | \quad x_k = j \leq \varepsilon \tag{3}$$

Recent works have tried to solve the problem using genetic algorithms and constraint propagation (Lambert, 2006), with local search techniques (Di Gaspero, 2008), with formal methods (HyperLingo) for the integer programming problems (Aguilar-Solis, 2008), with multiple optimization, using genetic algorithm of local search (Castro, 2009). All these studies have found the optimal for the three test cases included in CSPLib and in some cases also for the curriculums of their universities.

In (Aguilar-Solis, 2008) was proposed a modified BACP problem where it is considered constraints of academic load and total of courses within a specific range per period, i.e., not necessarily all periods will have the same ranges for their academic loads and number of courses; also add the restriction of to locate a course in a given period. This problem was modeled as an integer programming problem, and is reported to find optimum solutions, using a formal method, for some of its instances but not for all of them and solutions for the three instances included in CSPLib.

In this paper we solve the modified BACP problem using evolutionary strategies to find solutions to the instances that formal method could not to solve.

2 MODEL FORMULATION FOR BACP MODIFIED

In the model of interest proposed in (Aguilar-Solis, 2008) is considered to modify two constraints of the base formulation, the first one is to make flexible the course load per period and the second one is to make flexible the number of courses per period, i.e., that we can place different limits on course load and number of courses for each period. It also adds a restriction which allows the location of the courses in a specific period.

Parameters
Nta : Number of courses
Ntp : Number of academic periods
crd_i : Number of course credits i=1,…, Nta
mca_j: Minimum academic load allowed per period
Mca_j: Maximum academic load allowed per period
mna_j: Minimum number of courses per period
Mna_j : Maximum number of courses per period
c : Course it is desirable to locate between certain periods.
mpc_c: Minimum period of location of the course
Mpc_c : Maximum period of location of the course
C_j : Academic load

$$C_j = \sum_{i=1}^{Nta} crd_i * x_{ij} \qquad \forall j = 1,\ldots,Ntp \tag{4}$$

Decision Variables
C_j : Academic load for the period j=1,…, Ntp
Cmx : Maximum course load

$$X_{ij} = \begin{cases} 1 \text{ if course } i \text{ is assigned to period } j \\ 0 \text{ otherwise} \end{cases}$$

Objective Function

$$f_{objetive} = Min \{ \; Cmx \; \}$$

where $Cmx = Max \{ \; c_1, c_2, \ldots, c_{Ntp} \; \}$

Constraints
The load of the period j must be within the allowable range.

$$mca_i \leq C_j \leq Mca_j \qquad \forall j = 1,\ldots,Ntp \tag{5}$$

The number of courses of the period must be within the allowable range.

$$mna_j \leq \sum_{i=1}^{Nta} x_{ij} \leq Mna_j \qquad \forall j = 1,\ldots, Ntp \tag{6}$$

If the course b has the course a as prerequisite the course

$$x_{bj} \leq \sum_{r=1}^{j-1} x_{ar} \qquad \forall j = 2,\ldots,Ntp \tag{7}$$

Convenient location for the course c

$$\sum_{j=mpv_c}^{Mpc_c} x_{cj} = 1 \tag{8}$$

3 EVOLUTIONARY STRATEGIES

Evolutionary Strategies are optimization algorithms based on Darwin's theory of evolution, which states that only those individuals best adapted to their environment survive and reproduce. The procedure starts by choosing a random number of possible solutions in the search space to generate an initial population. Based on a fitness function evaluated for each possible solution, choose the best members of the population to take part in reproduction, this process is called selection. With the best members of the population selected genetic operations are carried out with the idea that new promising individuals will be evolved from their ancestors to produce an improved population. The genetic operations that generally are used are crossover and mutation, which in evolutionary strategies is the most important operation. The crossover is the combination of information from two or more individuals and mutation is the alteration of the information of a single individual (Michalewicz, 1999). There are several types of evolutionary strategies depending on the size of the population and how the individuals are replaced in the population prior to generating the new population. In our case we use an evolutionary strategy EE-(1+3), i.e., there is an initial population of a single individual and from this individual will generate 3 new individuals by mutation. Of these 4 individuals the best is choosing for the next population.

Evolutionary strategies were used, at least initially, to optimization problems of real functions, but are possible to use it successfully in other domains. In this paper we use evolutionary strategies in populations where individuals are vectors.

One element of the population is represented by a vector, where the position indicates the course and content of each position indicates the period to which it was assigned, as shown in figure 1.

0	1	2	3	4	5		59	60	61
1	1	3	1	2	2		9	9	0

Figure 1: Element of the Population.

In our case we used a population with a single individual so that the only operation performed is mutation, which consists in changing the period of a course of the curriculum that meets the prerequisites and restrictions of preference period.

We can consider that a balanced curriculum should have a uniform distribution of all the credits that make up the curriculum, so the fitness function used is the sum of the absolute error, which is calculated using the following formula.

$$Fitness\ (h) = \sum_{k=1}^{Ntp} \left| C_k - P \right| \tag{9}$$

Where C_k is the academic load of the period k calculated with the formula (4) and P is the average number of credits per period

$$P = \sum_{i=1}^{Ntp} C_i / Ntp \tag{10}$$

The initial population consists of the curriculum that we want to balance, this is a feasible solution.

Once that we have the first element of the population three new elements are generated through mutation. As the mutation is the random change of the value of a single element within the vector, randomly are chosen a course to be changed and the period where it will change.

Given the course and the period, are validated the restrictions prerequisites, load, course and time preference, if they are satisfied, the change is made, otherwise are selected randomly another course and period and redo the validation. This continues until to find the pair course - period that meets with the restrictions. This will generate 3 new individuals from the individual in the present population. The four individuals are evaluated by the fitness function (formula 9) and the best is selected for the next generation.

When is detected that a local optimum has been reached, a change in the process of mutation is made. Now, the mutation will change two elements of the vector, that is, now going to get the periods with more load and less load and will try to exchange two courses randomly between these two periods.

Having the two courses which will be exchanged, are evaluated the restrictions of prerequisite , load, course and period preference, if the exchange can be given a new individual is generated in otherwise the mutation is not done, the minimum period is marked as ineligible for the next selection and is cleared until that an improvement occurs.

4 RESULTS

The tests were carried out for the three base cases included in CSPLib and the cases proposed by (Aguilar-Solis, 2008) for which no solution could be found.

4.1 Base Cases

The base cases included in CSPLib are: BACP8, BACP10 and BACP12, whose features are shown in tables 1 and 2.

Table 3 shows the results obtained with the proposed algorithm; in all cases the optimum was reached.

Table 1: General features of curriculums.

Code	BACP8	BACP10	BACP12
# Total Courses	46	42	66
# Total credits	133	134	204
#Total Academic period	8	10	12
#Relation Prerequisite	33	34	65

Table 2: Additional features of the curriculums.

Code	BACP8	BACP10	BACP12
Min. Courses /period	2	2	2
Max. Courses / period	10	10	10
Min Load/ period	10	10	10
Max Load/ period	24	24	24
#Courses with location	0	0	0

Table 3: Results summary.

Code	Optimum	Average Iterations	Average time (min.)
BACP 8	17	57.6	1.5
BACP 10	14	87.7	1.7
BACP 12	17	162.0	2.5

The academic load per period obtained by the algorithm is shown in table 4.

Table 4: Solution found for BACP 8.

Period	Load	Courses
1	17	7
2	17	5
3	17	5
4	17	6
5	17	6
6	17	6
7	15	5
8	16	6

4.2 Proposed Cases

The cases not included in library CSPLib used to test this algorithm are taken from (Aguilar-Solis, 2008), the first is one for which could not always find the optimal and the second is where the optimum never was found. The features of these two problems are shown in tables 5 y 6.

Table 5: General features of curriculums.

Code	Ici-06	Ind-06
# Total Courses	61	61
# Total credits	488	376
#Total Academic period	9	9
#Relation Prerequisite	48	47

Table 6: Additional features of the curriculums.

Code	Ici-06	Ind-06
Min. Courses /period	5	4, 4, 4, 4, 4, 4, 4, 4, 2
Max. Courses/ period	8	9, 9, 9, 9, 9, 9, 9, 9, 4
Min Load/ period	20	20, 20, 20, 20, 20, 20, 20, 20, 15
Max Load/ period	60	60, 60, 60, 60, 60, 60, 60, 60, 40
#Courses with location	15	21

In tables 7 and 8 is showing the courses that have preference of location in each of the curriculums, Ici-06 and Ind-06 respectively.

Table 7: Preference of location Ici-06.

Course Code	Minimum Period	Maximum Period
C07001	7	9
C07002	7	9
C07003	7	9
CIV200	1	2
CIV400	6	9
CIV401	8	9
CIV403	6	9
MAT005	1	5
MAT006	1	5
MAT008	1	5
MAT009	1	5
OI103101	1	4
OI103102	1	4
OI103103	1	4
OI103104	1	4

Table 8: Preference of location Ind-06.

Course Code	Minimum Period	Maximum Period
C12001	7	9
C12002	7	9
C12003	7	9
C12004	8	9
FHU001	1	6
FHU002	1	6
FHU003	1	6
IND100	1	2
IND208	4	6
IND212	4	6
IND214	6	8
IND400	7	9
LPCI	1	6
LPCII	1	6
OH25001	1	6
OI103101	1	6
OI103102	1	6
OI103103	1	6
OI103104	1	6
SSC001	5	9
SSP002	5	9

Table 9 shows the results obtained with the algorithm; in all cases the optimum was reached.

Table 9: Results summary.

Code	Optimum	Average Iterations	Average time (min.)
Ici-06	55	57.6	16
Ind-06	44	87.7	19.7

The academic load per period obtained by the algorithm is shown in Table 10.

Table 10: Solution found for Ici-06.

Period	Load	Courses
1	54	7
2	54	6
3	54	6
4	54	7
5	55	6
6	55	6
7	54	8
8	54	7
9	54	8

5 CONCLUSIONS

In this paper we present the solution, using evolutionary strategies, for a modified Balanced Academic Curriculum Problem, where the load for each period can be equal or different and is allowed to have some courses in a specific period. In a previous work is showed that is possible to find solutions with HyperLingo for some of the instances of the problem, but not for all of them. However by the results obtained was proved that the use of evolutionary strategies helps to find solutions to the problems that could not be resolved with the formal method.

REFERENCES

Aguilar-Solís J. A., *Un modelo basado en optimización para balancear planes de estudio en Instituciones de Educación Superior*, PhD Thesis, Puebla: UPAEP, 2008.

Castro, C., Crawford, B., Monfroy, E., A Genetic Local Search Algorithm for the Multiple Optimisation of the Balanced Academic Curriculum Problem, In *Proceedings of MCDM, pages 824-832*, Berlin: Springer-Verlag, 2009.

Castro, C., Manzano, S., Variable and value ordering when solving balanced academic curriculum problem, *Proc. of the ERCIM Working Group on Constraints*, 2001.

Di Gaspero, L., Schaerf, A., Hybrid Local Search Techniques for the Generalized Balanced Academic Curriculum, In *Proceedings of HM, pages 146-157*, Berlin: Springer-Verlag, 2008.

Lambert, T., Castro, C., Monfroy, E., Saubion, F., Solving the Balanced Academic Curriculum Problem with an Hybridization of Genetic Algorithm an Constraint Propagation, In *Proceedings of ICAISC, pages 410-419*, Berlin: Springer-Verlag, 2006.

Michalewicz, Z., *Genetic Algorithms + Data Structures = Evolution Programs*, Berlin: Springer-Verlag, 1999.

Salazar, J., *Programación matemática*, Madrid: Diaz de Santos, 2001.