32. mednarodna konferenca o razvoju organizacijskih znanosti
PAMETNA ORGANIZACIJA
Talenti. Vitka organiziranost. Internet stvari.
20. - 22. marec 2013, Portorož, Slovenija

Evalvacija različnih pristopov za izdelavo urnika v slovenskih osnovnih šolah

Evaluation of different approaches for solving primary school timetabling problems in Slovenia

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Povzetek
Razporejanje in sestavljanje urnikov predstavlja velik problem za vse sestavljalce. Razvili smo program za sestavljanje šolskih urnikov, ki uporablja evolucijski algoritem (EA). Program Algit TimeTable (slo. - iUrnik), smo primerjali s programom, ki ga šole v Sloveniji trenutno največ uporabljajo. Ocenili smo njihov trenutni urnik in pod istimi pogoji in zahtevami še urnik, ki ga je "izračunal" naš program.

Ključne besede: šolski urnik, evolucijski algoritem, ocenjevanje

Abstract
Scheduling and timetable creation represents a big problem for time table creators. We developed software for creating (calculating) time tables, that uses evolutionary algorithm (EA). We compared our software – Algit Timetable (slo. – iUrnik) with the most commonly used software Slovenian schools use nowadays. We evaluated their current time tables and under the same conditions and demands, we compared it with the timetable our program had created.

Keywords: school time table, evolution algorithm, evaluation

1 Introduction

Scheduling workers and school time tabling have been a huge problem for all involved in the process for a very long time. Restrictions, legal and human, bring a huge amount of combinations, which are usually impossible to solve by traditional approaches. Trying to create today's time table with pen and paper is practically impossible. The problem involves the scheduling of classes, students, teachers and rooms at a fixed number of time slots, in a way that satisfies a set of hard constraints and minimize the cost of a set of soft constraints (Ghaemi et. al, 2007). Only in a middle-sized school with 200 students, 30 teachers, 20 selective groups of elective subjects on 9 levels and 15 heterogeneous groups we have more than 10^{55} combinations.

Schools in Slovenia are using different programs to solve the problem of creating time tables (GpUntis, School Time, Algit TimeTable (iUrnik), ASC Time Table, etc.). There is a vast variety of School Timetabling formulations, which makes it difficult to compare the different solution approaches (Avella et. al, 2007). We have to consider different approaches and aspects:

- Level of automatization for calculating school time table – manual or automatic calculation of all subject and demands, without human interference (situation such as "I cannot allocate this" cannot happen).
- Support for partial groups (1/10, 1/3, 1./10, 1./3,…).
- Support for half hours in A and B time table.
- Student level data input (extra help, morning care, day care).
- Process of elective subjects.
- Creation of a timetable for any Slovenian school.
- Number of teachers and classrooms based on the number of groups – some classrooms can be used 100% and that is the key indicator of complexity for calculating the time table.
- Horizontal and vertical combining of classes.
- Support for different school hour length (e.g. 45 minutes or 60 minutes) considering the availability of teachers and classrooms.
- Teachers' and students' transitions between different locations.
- Practical limitations (e.g. intervals of teacher's teaching hours – minimal 2 hours maximal 6 hours per day).

In this article we took time tables of 3 different Slovenian primary schools of different sizes (from 300 to 700 students), involving only classes from 6 to 9 where, based on Slovenian laws, the real problems of scheduling occurs, because students have elective subjects, heterogeneous groups, level lessons, gender and non-gender division, etc., and compared them with the results our approach is able to achieve.

Solving problems using artificial intelligence (AI) is getting more frequent or sometimes it is even necessary, while its usage is sometimes limited with "real-time" solutions. Search space where possible solutions can be found, can quickly become so big that "brute force" solutions cannot be used since it would require too much time to find the solution. EA can solve some of very complex problems in a huge search space. The principle is known at least from Darwinian times on, but there are only a few well known practical solutions. Some problems are simplified and can be solved with a lot of different algorithms but the results do not take into consideration all the limitations and conditions. The main difference between EP (evolution programming) and GAs is that the typical GA involves encoding the problem solutions as a string of representative signs, i.e., binary representation (Goldberg et. al, 1989, Mitchel et.al, 1994). In EP, the representation comes from the nature of the problem which permits a simpler representation of the solution. Furthermore, EP generally depends on mutation process and not on the recombination like crossover to produce offspring (Aldasht et. al, 2009).

In our comparison we did not focus directly on algorithm that calculates or creates a time table but evaluated it despite its result. Furthermore some of the elements were not evaluated, such as the speed of data input, calculation time and time needed for users to learn how to work with the program. The main focus of our comparison was the result.

2 Time table comparison and criteria

Comparisons have been done for primary school timetables (Primary schools have a very complicated curriculum and therefore creating a time table is the most challenging there). As stated before, the comparisons represent a great challenge. What is a good time table? Is that the one where there are no idle students? No idle hours for teachers? Etc. The criteria have been based on our field experiences of around 60 schools that use Algit's time table program Algit TimeTable (2013) and their demands. The criteria are not the only indicator of a good time table. There are also some simplifications that are necessary for competitive programs to make it even possible for them to calculate the timetable completely. Usual simplifications are:

- Termination of half hours for some subjects and manual combinations of half hours.
- Use of heterogeneous groups instead of level subjects - where there are not enough teachers for simultaneity.
- Gender division where it is not recommended.
- Elective and interest classes occurring at the same time with the same students.
- Not all events are inserted – individual expert help for students, because it complicates the calculation, teachers' meetings, and other students' activities.
- Calculating time table only for classes from 6 to 9 and not for the whole school.
- Groups of elective subjects are directed by teachers and are adapted for time table not for students.

The comparison was made only with Gp-Untis that is supposed to automatically calculate the time table. Time tables were evaluated according to the criteria shown in Table 1.

Error	Ponder	Error	Ponder
inconsistency errors	1e+10	idle hours position	1e+3
subjects apart daily	1e+10	hours per day 4-7	1e+6
subject distribution per week	1e+5	hours per student day 4-7	1e+6
subject order per day	1e+0	idle hours per teacher	1e+6
subject order per week	1e+2	teacher's day load	1e+5
hours per schedule	1e+4	locations matching priority	1e+6
hours per class	1e+4	locations matching event	1e+3
idle student hours	1e+8	locations matching teacher	1e+0
idle hours per student	1e+7		

Table 1: Criteria for time table evaluation with corresponding ponders

Idle students are counted for 14 days. The smaller the error gets the better the time table is.

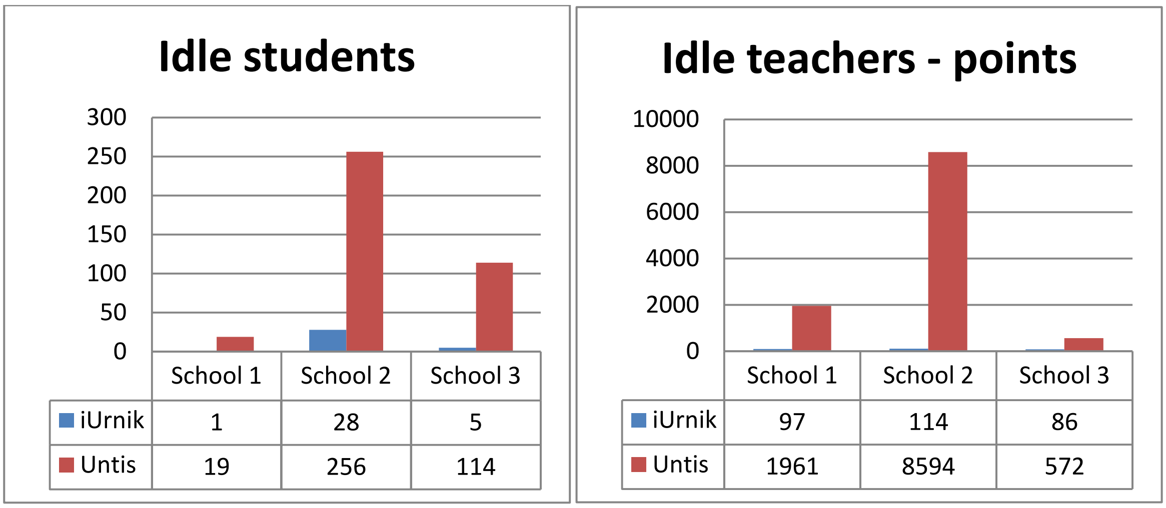
3 Results

The comparison of time tables has been summarized in the table 2.

	Algit TimeTable	**Gp - Untis**
Idle students	Very little or 0	A lot
Idle teachers	Very little or 0	A lot
Human interference	Not necessary	Sometimes necessary
Simplifications	Not necessary	Necessary
Half hours' support	Total	Manual help
Process of elective subjects	Completely	Only group separation
Suplences	Complete	unknown
Speed of calculation	Slow	Fast

Table 2: Time table comparison

In picture 1, we can see the comparison of idle students and idle teachers (points) for all three schools. The smaller the amount of points, the better the time table for teachers.



Picture 1: Idle students and idle teachers – points

3.1 Examples

These are the examples of schools in Slovenia, where time tables are done with a program Gp-Untis.

3.1.1 Example 1

- 1 - 2012_original: the original time table of school.
- 1 - 2012_original_released: same demands from school as original, calculated with Algit TimeTable.

- 1 - 2012_released: same demands from school as original, less restrictions calculated with Algit TimeTable.
- 1 - 2012_non-gender: same demands from school as original, non-gender division calculated with Algit TimeTable.

School has less than 300 students, classrooms limitations and only one teacher of PE, therefore he/she is a big limitation for time table. The comparison shows there are more possibilities for time table optimization. Number of idle students can be reduced and teachers can have a better time table. We also did a time table where subjects are only once per day. Results are shown in next table.

Criteria	**Original**	**Original released - Algit TimeTable**	**Released - Algit TimeTable**	**Released non-gender -- Algit TimeTable**
Total error	4.239.046.139	300.515.269	176.208.507	9.308.441.313
subject distribution per week	63	60	45	41
subject order per day	4.518	4.651	4.692	4.296
subject order per week	156	136	168	180
hours per schedule	554	584	610	625
hours per class	3,217	3,204	3,178	3,106
idle student hours	19	1	0	0
idle hours per student	25	1	0	0
idle hours position	203	11	0	0
hours per day 4-7	4	2	2	3
hours per student day 4-7	18	2	2	2
idle hours per teacher points	1961	97	85	9216
teacher's day load	288	246	268	260
locations matching priority	33	21	18	20
locations matching event	13	6	7	9
locations matching teacher	21	18	15	17
Calculation time		12 hours – 3	14 hours	20 hours

Table 3: Results for school 1

3.1.2 Example 2

- 2-2012_original: the original time table of school.
- 2-2012_original_released: same demands from school as original, calculated with Algit TimeTable.
- 2-2012_released_1: same demands from school as original, calculated with Algit TimeTable, new groups.

Comparison in table 4 shows that there are still some possibilities for optimization. Number of idle students could be lowered and also some improvement for the teachers could be done. Also for one class there could be a time table where subject SLJ occurs only once a day and sculpturing does not occur the same time as the choir.

Criteria	Original	Original released – with Algit TimeTable	Released – with Algit TimeTable
Total error	38.443.143.576	3.350.957.716	5.321.094.232
subject distribution per week	54	96	77
subject order per day	9,139	9,379	9,097
subject order per week	284	253	201
hours per schedule	580	550	580
hours per class	5,386	4,834	4,910
idle student hours	256	28	45
idle hours per student	406	28	53
idle hours position	2,645	280	462
hours per day 4-7	42	24	32
hours per student day 4-7	66	40	48
idle hours per teacher points	8,594	114	121
teacher's day load	94	262	220
locations matching priority	4	3	5
locations matching event	1	3	3
locations matching teacher	37	37	35
Calculation time		12 hours	14 hours

Table 4: Results for school 2

3.1.3 Example 3

- 3-2012_original: the original time table of school.
- 3-2012_original_released: same demands from school as original, calculated with Algit TimeTable.
- 3-2012_released: same groups and demands as original, 1hour of mandatory presence.

Time table (original) is a bit simplified. SLJ in 8 and 9 class should be 3,5 hours per week in 8 class and 4,5 hours per week in 9 class but instead it is 4 hours for each (in 2 years a sum is the same) and ODS is not only ½ hour but 1 hour. The same goes for the BIO, GEO, GVZ and some others.

Comparison in table 5 shows that there are still some possibilities for optimization. Number of idle students can be lowered and also for teachers some improvement could be done. Idle students are also those who come to school after 1 hour but since we did not have the list of those students they are considered as idle, otherwise the number would be lowered for 50 on 14 days and consequently time table would improve.

Criteria	Original	Original released – with Algit TimeTable	Released– with Algit TimeTable
Total error	13.604.871.450	697.157.844	143.843.095
subject distribution per week	51	65	38
subject order per day	21,542	22,935	24,188
subject order per week	119	149	159
hours per schedule	490	490	490

hours per class	3,242	3,246	3,350
idle student hours	114 (64)	5	0
idle hours per student	158	5	0
idle hours position	1,616	56	0
hours per day 4-7	0	0	0
hours per student day 4-7	0	0	0
idle hours per teacher points	572	86	89
teacher's day load	78	112	106
locations matching priority	1	6	2
locations matching event	2	4	3
locations matching teacher	8	9	7
Calculation time		4 hours	4 hours

3.2 Results interpretation

The results have shown a great improvement in the quality of the time tables if calculated with Algit TimeTable. The number of idle students has been (can be) reduced on all three schools. The same goes for the idle hours of teachers. Our calculation times are bigger than the ones of the software which are currently in use by schools. However, since the time table is not created every day but usually during summer holidays, calculation time cannot be considered as an important factor. Even if the time table has to be calculated again because of some bigger changes (new teachers' work time, new students, etc.) we can see it can be done in less than weekend time (2 days) because the program starts from already calculated time table. The suplences during the week are created separately and are created instantly.

4 Conclusion

We have shown that using EA gets us some very good results for school time table problem. As conditions in Slovenian school system are very complicated its use gets more frequent. We can see there are less idle students, students have a more compact time table, teachers have a better day load distribution, etc. This leads to more satisfied students, teachers, school administration and students' parents.

The automation of the timetable problem is thus an important task as it saves a lot of man-hours work to institutions and provides optimal solutions with constraint satisfaction that can boost productivity, quality of education and services (Chaudhuri, 2010). However, large-scale timetables, such as university timetables, may need many hours of work spent by qualified person or a team in order to produce high quality timetables with optimal constraint satisfaction and optimization of timetable's objectives at the same time (Legierski, 2005). With Algit TimeTable the calculation of time table is completely automated, the only task of the time table creator is data input. There is no human interference in calculation process. Also time for users to get familiar with the program is very short. Furthermore, the school administrations has a total control of what is happening at school (when students are idle, which class or teacher has the worst/best time table, distributions, etc). The more school data that is inserted into the program the closer to the optimum the school time table gets. We call our program Algit TimeTable an "intelligent program", since it calculates time table completely alone and no human interference is needed as long as initial conditions are set right (enough time alocated for teachers, as many rooms as necessary, etc.). Results of Algit TimeTable surpass the results of humans or other time table programs where human interference or help is needed.

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