ISSN 1392 – 124X INFORMATION TECHNOLOGY AND CONTROL, 2005, Vol. 34, No. 2

SCHOOL SCHEDULE OPTIMISATION PROGRAM

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Abstract. The system for school schedule creation and optimization solves a very difficult, important and practical problem. This system allows the user to not only see the initial and optimized school schedule in a simple and understandable form, but also to choose optimization methods and criteria. This system displays a full school schedule, individual schedules for the teachers and students not only on the desktop, but also in the files. The user may choose the new optimization methods and/or criteria and get new initial data and results.

1. Indroduction

Basicly all schools in Lithuania are profiled now. That's because the former teaching models enforced the students to learn everything and specialize only on account of additional time. Today all wishes and abilities of a student are taken into consideration. That way the number of compulsory classes was decreased. So the student may choose the classes that correspond to his likes and abilities. As there are many students in school who select different subjects a big problem of schedule construction arises.

Many companies are doing their best to make this work easy and to create practical and simple schedule making optimization programs. Lately we got acquainted with several schedule making programs such as:

1. „MIMOSA“ – released by the company „ MIMOSA software OY:
2. „RECTOR“ – released by „Системы-Программы-Сервис;
3. „aSc Timetables 2004‟ – released by „Applied Software Consultants s.r.o‟;

2. „MIMOSA“ and “aSc Timetables 2003”

Both programs are similar to each other. The main idea of this program is very simple. Practically it is impossible to make a good school schedule automatically. So the program does not try to do that either. It makes only the initial schedule where the user may easily set and regulate the school schedule giving an effective and necessary information. The program does not require any special computers or any particular knowledge. It should work in any kind of computer where Windows95 is able to operate. The program is good, data are easy to put using the “MS Excel”, but the user must regulate the schedule manually. This is very hard when there are so much data. If something would need to be changed in the initial data, practically the whole schedule should be constructed anew. “MIMOSA” requires about 50% of human resources.

3. „RECTOR“

The main idea of this program and “MIMOSA” is the same. This program also does not require any special computers or any particular knowledge. Compare to “MIMOSA” the advantage of this program is that it is released in the Lithuanian language. It should work in any kind of computer where Windows95 is able to operate. Similarly as in “MIMOSA” the user must complete the schedule manually. This becomes a big problem when there are a lot of students and some changes appear.

4. „School schedule optimization program“

Recently we are working on the program called “School schedule optimization program”. This program creates the initial schedule of the profiled classes. Then it is followed by optimization of this schedule which allows to minimize the number of “windows” for students and for teachers. As every student may choose his favorite subjects the schedule must be made individually for every student. But the schedule must be acceptable not only for students but also for the teachers. Some physical restrictions must be considered too:

- Schedule situations when a student or a teacher participates in two lessons at the same time are not allowed to occur.

- The student or teacher works a full day with no break (except for breaks between lessons)
- The student or the teacher has many breaks during a day (every second or third lesson)
- The teacher has lessons on his "free" day. (a lot of teachers have several jobs and their lessons shall not duplicate)

This program facilitates the schedule making for profiled classes. The user participates only in preparation of the data file, sending the data file to the server and getting the results. The program makes the schedule according to indicated restrictions, performs optimization, calculates penalty points for each schedule variant and displays the best schedule according to the number of penalty points.

The program is written in the Java language, so it could run not only under Windows but also under Linux operating system. As a personal computer or internet may be used for this program we will analyze the more usual case when the program is executed with the help of internet.

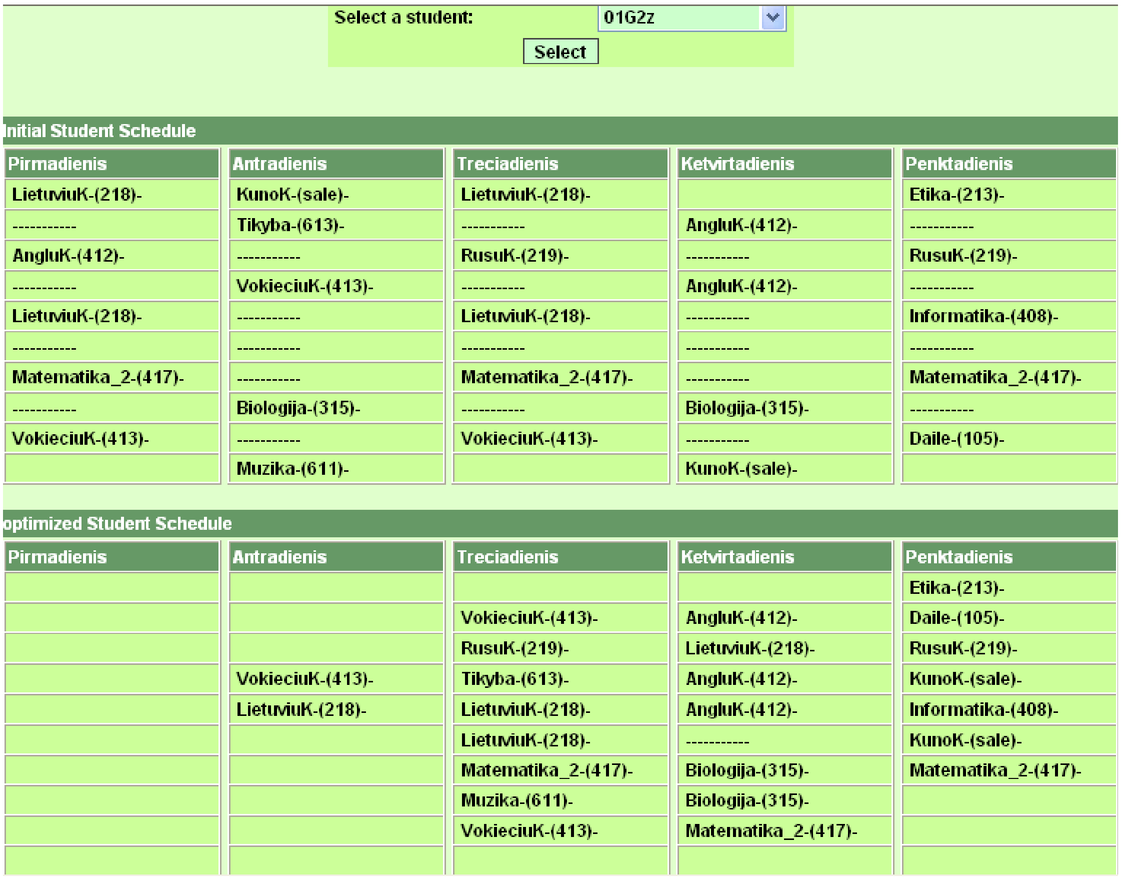
5. Comparison of results

5.1. The "School schedule optimization program"

Since the initial data had groups divided into subgroups the program displayed the results in subgroups too. This can be seen in Figures 1 and 2. The schedule displayed in the upper part of the figures represents the initial data (before optimization). The schedule given below it is already optimized. That way the user may see optimized and initial individual schedules of every teacher and also the complete initial school schedule.

5.2. Results obtained using "aSc Timetables 2003"

Since the initial data had groups divided into subgroups the program displayed the results in subgroups too. This can be seen in Figure 3 where the schedules of all three groups are displayed. Also this program allows to see the whole schedule of students (student groups), teachers (work schedule of all teachers in one window) and classrooms (schedule of all classrooms in one window). However this program does not display the schedules of individual groups and subgroups.



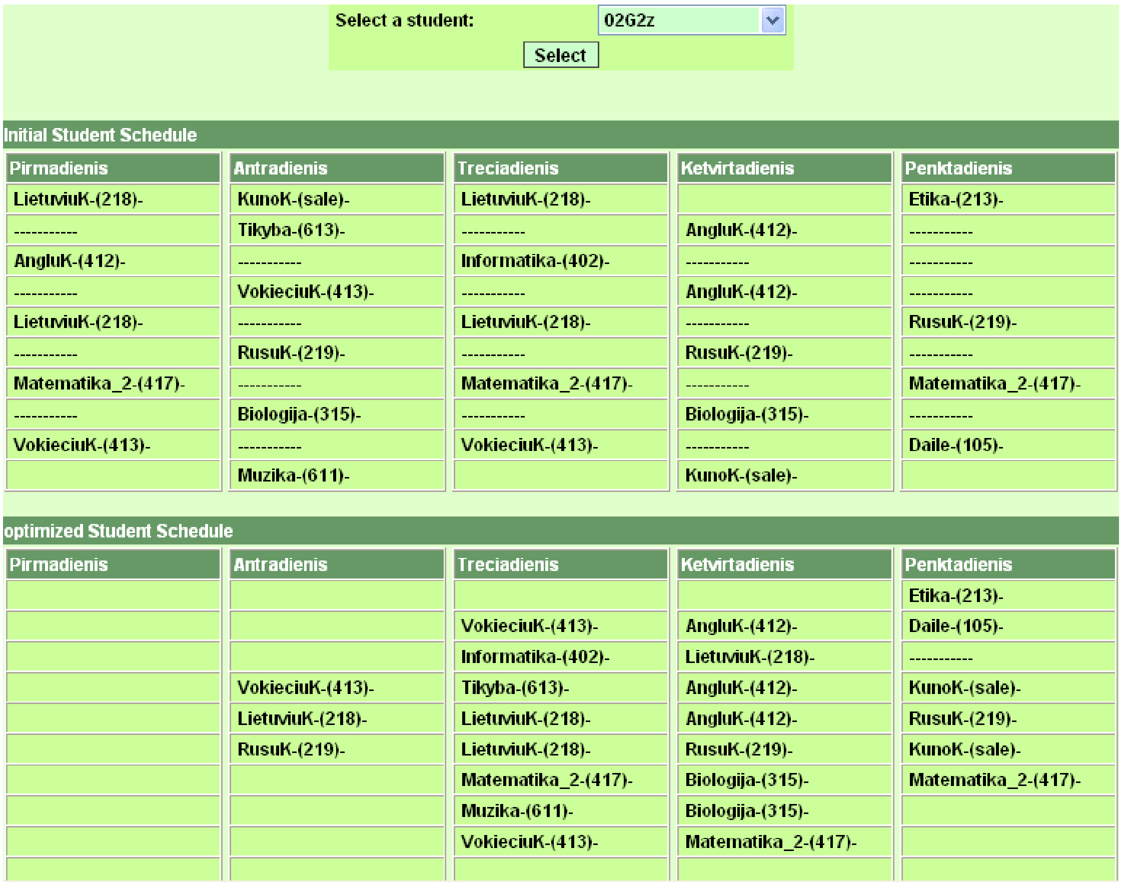
Initial Student Schedule

Pirmadienis	Antradienis	Treciadienis	Ketvirtadienis	Penktadienis
LietuviuK-(218)-	KunoK-(sale)-	LietuviuK-(218)-		Etika-(213)-
-----------	Tikyba-(613)-	-----------	AngluK-(412)-	-----------
AngluK-(412)-	-----------	RusuK-(219)-	-----------	RusuK-(219)-
-----------	VokieciuK-(413)-	-----------	AngluK-(412)-	-----------
LietuviuK-(218)-	-----------	LietuviuK-(218)-	-----------	Informatika-(408)-
-----------	-----------	-----------	-----------	-----------
Matematika_2-(417)-	-----------	Matematika_2-(417)-	-----------	Matematika_2-(417)-
-----------	Biologija-(315)-	-----------	Biologija-(315)-	-----------
VokieciuK-(413)-	-----------	VokieciuK-(413)-	-----------	Daile-(105)-
	Muzika-(611)-		KunoK-(sale)-	

optimized Student Schedule

Pirmadienis	Antradienis	Treciadienis	Ketvirtadienis	Penktadienis
				Etika-(213)-
		VokieciuK-(413)-	AngluK-(412)-	Daile-(105)-
		RusuK-(219)-	LietuviuK-(218)-	RusuK-(219)-
	VokieciuK-(413)-	Tikyba-(613)-	AngluK-(412)-	KunoK-(sale)-
	LietuviuK-(218)-	LietuviuK-(218)-	AngluK-(412)-	Informatika-(408)-
		LietuviuK-(218)-	-----------	KunoK-(sale)-
		Matematika_2-(417)-	Biologija-(315)-	Matematika_2-(417)-
		Muzika-(611)-	Biologija-(315)-	
		VokieciuK-(413)-	Matematika_2-(417)-	

Figure1. Group 2Gz, first subgroup, the results of schedule making using the program "School schedule optimization program"



Select a student: 02G2z

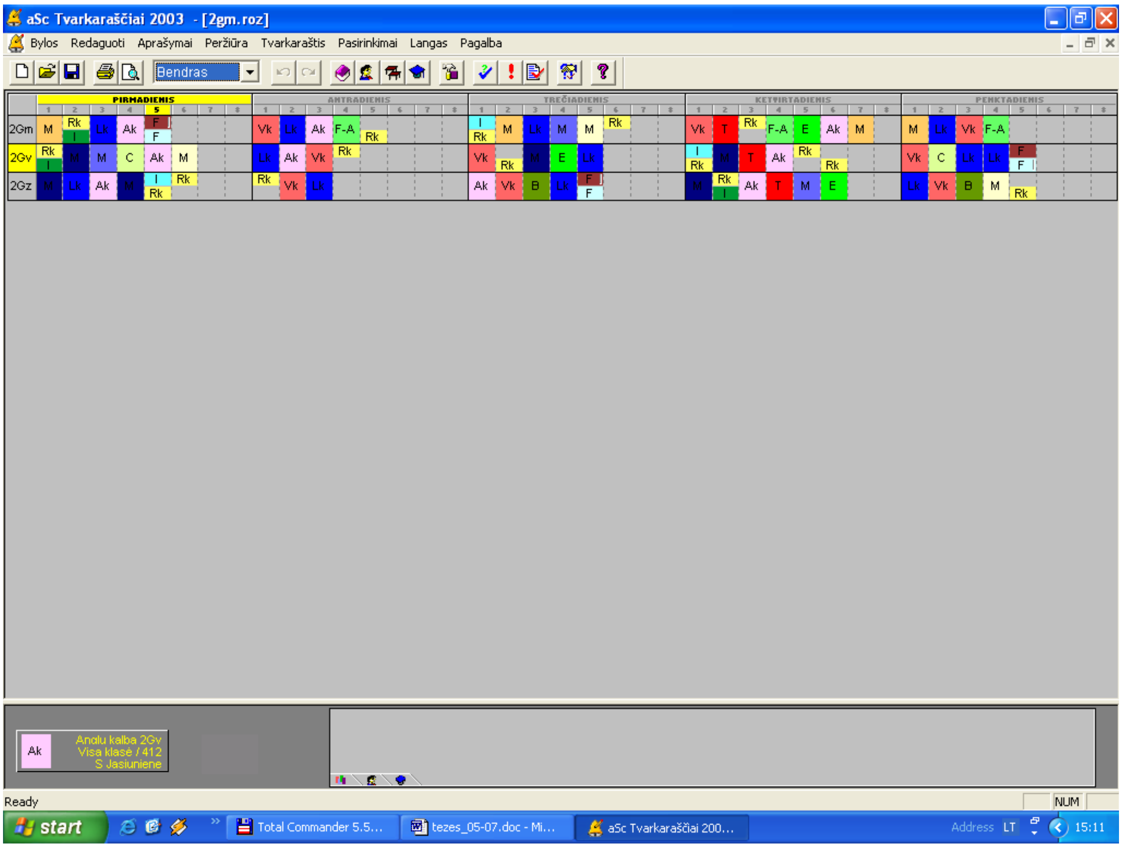
Initial Student Schedule

Pirmadienis	Antradienis	Treciadienis	Ketvirtadienis	Penktadienis
LietuviuK-(218)-	KunoK-(sale)-	LietuviuK-(218)-		Etika-(213)-
-----------	Tikyba-(613)-	-----------	AngluK-(412)-	-----------
AngluK-(412)-	-----------	Informatika-(402)-	-----------	-----------
-----------	VokieciuK-(413)-	-----------	AngluK-(412)-	-----------
LietuviuK-(218)-	-----------	LietuviuK-(218)-	-----------	RusuK-(219)-
-----------	RusuK-(219)-	-----------	RusuK-(219)-	-----------
Matematika_2-(417)-	-----------	Matematika_2-(417)-	-----------	Matematika_2-(417)-
-----------	Biologija-(315)-	-----------	Biologija-(315)-	-----------
VokieciuK-(413)-	-----------	VokieciuK-(413)-	-----------	Daile-(105)-
	Muzika-(611)-		KunoK-(sale)-	

optimized Student Schedule

Pirmadienis	Antradienis	Treciadienis	Ketvirtadienis	Penktadienis
				Etika-(213)-
		VokieciuK-(413)-	AngluK-(412)-	Daile-(105)-
		Informatika-(402)-	LietuviuK-(218)-	-----------
	VokieciuK-(413)-	Tikyba-(613)-	AngluK-(412)-	KunoK-(sale)-
	LietuviuK-(218)-	LietuviuK-(218)-	AngluK-(412)-	RusuK-(219)-
	RusuK-(219)-	LietuviuK-(218)-	RusuK-(219)-	KunoK-(sale)-
		Matematika_2-(417)-	Biologija-(315)-	Matematika_2-(417)-
		Muzika-(611)-	Biologija-(315)-	
		VokieciuK-(413)-	Matematika_2-(417)-	

Figure 2. Group 2Gz, second subgroup, the results of schedule making using the program “School schedule optimization program”



	PIRMADIENIS							
	1	2	3	4	5	6	7	8
2Gm	M	Rk I	Lk	Ak	F F			
2Gv	Rk I	M	M	C	Ak	M		
2Gz	M	Lk	Ak	M	I Rk	Rk		

	ANTRADIENIS							
	1	2	3	4	5	6	7	8
2Gm	Vk	Lk	Ak	F-A	Rk			
2Gv	Lk	Ak	Vk	Rk				
2Gz	Rk	Vk	Lk					

	TREČIADIENIS							
	1	2	3	4	5	6	7	8
2Gm	I Rk	M	Lk	M	M	Rk		
2Gv	Vk	Rk	M	E	Lk			
2Gz	Ak	Vk	B	Lk	F F			

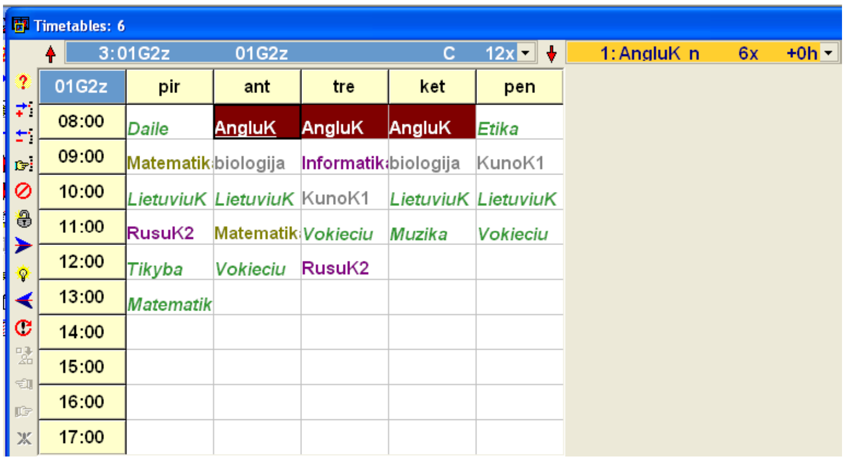
	KETVIRTADIENIS							
	1	2	3	4	5	6	7	8
2Gm	Vk	T	Rk	F-A	E	Ak	M	
2Gv	I Rk	M	T	Ak	Rk	Rk		
2Gz	M	Rk I	Ak	T	M	E		

	PENKTADIENIS							
	1	2	3	4	5	6	7	8
2Gm	M	Lk	Vk	F-A				
2Gv	Vk	C	Lk	Lk	F F			
2Gz	Lk	Vk	B	M	Rk			

Ak
Anglu kalba 2Gv
Visa klasė / 412
S Jasiuniene

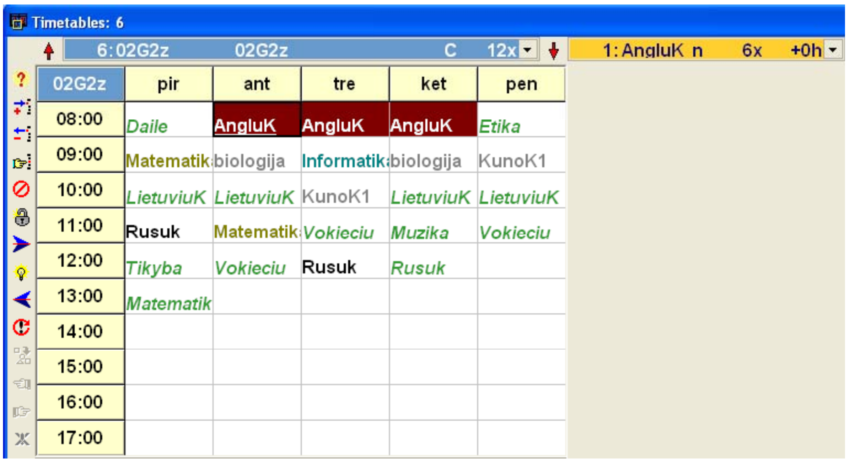
Ready

Figure 3. Results of school schedule making for all three groups using “aSc Timetables 2003”



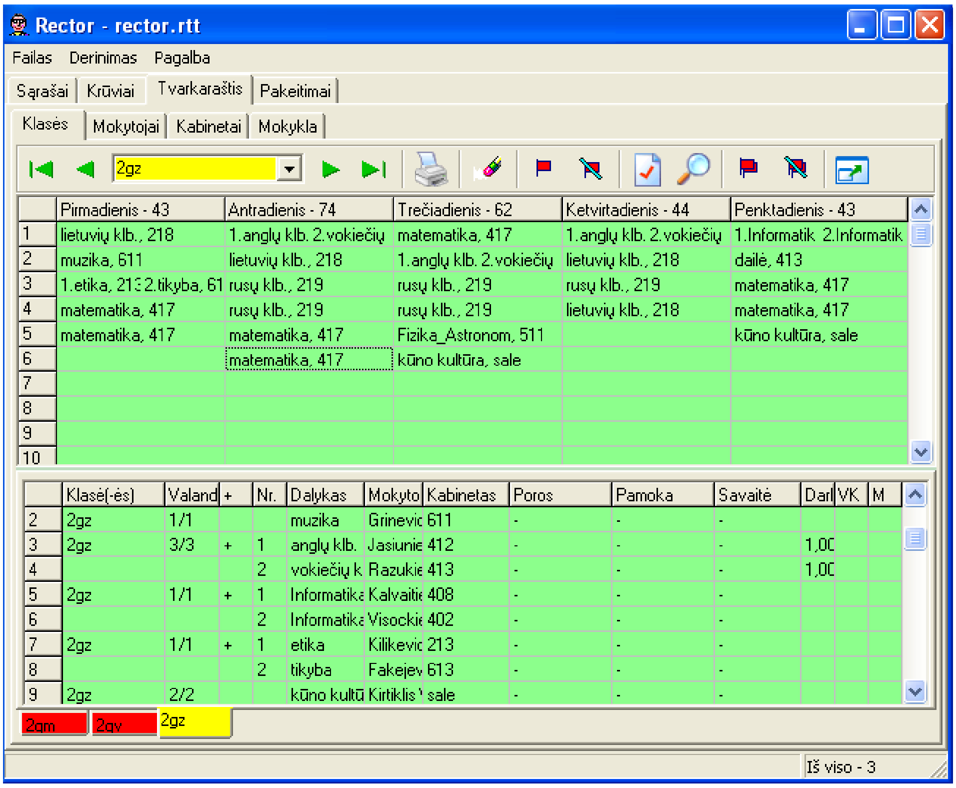
01G2z	pir	ant	tre	ket	pen
08:00	Daile	AngluK	AngluK	AngluK	Etika
09:00	Matematik	biologija	Informatik	biologija	KunoK1
10:00	LietuviuK	LietuviuK	KunoK1	LietuviuK	LietuviuK
11:00	RusuK2	Matematik	Vokieciu	Muzika	Vokieciu
12:00	Tikyba	Vokieciu	RusuK2		
13:00	Matematik				
14:00					
15:00					
16:00					
17:00					

Figure 4. Group 2Gz, first subgroup, the results of schedule making using the program "MIMOSA"



02G2z	pir	ant	tre	ket	pen
08:00	Daile	AngluK	AngluK	AngluK	Etika
09:00	Matematik	biologija	Informatik	biologija	KunoK1
10:00	LietuviuK	LietuviuK	KunoK1	LietuviuK	LietuviuK
11:00	Rusuk	Matematik	Vokieciu	Muzika	Vokieciu
12:00	Tikyba	Vokieciu	Rusuk	Rusuk	
13:00	Matematik				
14:00					
15:00					
16:00					
17:00					

Figure 5. Group 2Gz, second subgroup, the results of schedule making using the program "MIMOSA"


Rector - rector.rtt
Failas Derinimas Pagalba
Sąrašai Krūviai Tvarkaraštis Pakeitimai
Klasės Mokytojai Kabinetai Mokykla
2gz

	Pirmadienis - 43	Antradienis - 74	Trečiadienis - 62	Ketvirtadienis - 44	Penktadienis - 43
1	lietuvių klb., 218	1.anglų klb. 2.vokiečių	matematika, 417	1.anglų klb. 2.vokiečių	1.Informatik 2.Informatik
2	muzika, 611	lietuvių klb., 218	1.anglų klb. 2.vokiečių	lietuvių klb., 218	dailė, 413
3	1.etika, 21: 2.tikyba, 61	rusų klb., 219	rusų klb., 219	rusų klb., 219	matematika, 417
4	matematika, 417	rusų klb., 219	rusų klb., 219	lietuvių klb., 218	matematika, 417
5	matematika, 417	matematika, 417	Fizika_Astronom, 511		kūno kultūra, sale
6		matematika, 417	kūno kultūra, sale		
7					
8					
9					
10					

	Klasė(-ės)	Valand	+	Nr.	Dalykas	Mokyto	Kabinetas	Poros	Pamoka	Savaitė	Darl	VK	M
2	2gz	1/1			muzika	Grinevic	611	-	-	-			
3	2gz	3/3	+	1	anglų klb.	Jasiunie	412	-	-	-	1,0C		
4				2	vokiečių k	Razukie	413	-	-	-	1,0C		
5	2gz	1/1	+	1	Informatika	Kalvaitie	408	-	-	-			
6				2	Informatika	Visockie	402	-	-	-			
7	2gz	1/1	+	1	etika	Kilikevic	213	-	-	-			
8				2	tikyba	Fakejev	613	-	-	-			
9	2gz	2/2			kūno kultū	Kirtiklis '	sale	-	-	-			

Figure 6. Group 2Gz, the results of schedule making using the program "RECTOR"

5.3. Results of program "MIMOSA"

Since the initial data had groups divided into subgroups the program displayed the results in subgroups too. Both Figures 4 and 5 show only the schedules of one group. The program displays only individual schedules of a group or a subgroup.

5.4. Results of the program "RECTOR"

Since the initial data didn't have the groups divided into subgroups the program displayed the results in groups too (see Figure 6). The figure displays the schedule of one group and it had to be set manually. The program doesn't even help to set the schedule. The other groups in red may be seen at the bottom of the window.

6. The experimental investigation of models

6.1. Description of investigation methods

Table 1. Methods used for investigation.

Method's name	Creator of method	Characteristics of method
Exkor	Coordinate search of Bayes by Zilinskas	It's a realization of Viener process; Viener process consists of Brown's movements. This method prognosticates that one will win more with every try. It's a one-dimensional process. It features Markov: an auxiliary problem is solved to get the best result. According to the results the calculations are performed.
Bayes	Bayes by Mockus	This is an old realization of "**Exkor**" method. Moreover, this method is a statistic one.
LBayes	Casual approximation by Mockus	It's a statistic approximation. The function is convex but only values with bias are measured. This method is local.
Globt	Grouping by Thorn	This method works as follows: first the accidental clusterization is performed. Then the method moves to a better direction. The clusters are then optimized according to heuristic features and only the "good" clusters are selected. The process is repeated again but only with the good clusters until only one cluster is left. All the calculations are done with this only cluster.
Mig1	Monte Carlo	This method is reverse to "**Exkor**".

6.2. Results of SA investigations

The initial data are the same. Penalty points are rated as follows:

Window in student's schedule	10
Window in teacher's schedule	1
Two, one after another, impossible lessons are set	5
Teacher's lessons are scheduled on the "free" days	10
Number of lessons a day	10
Number of iterations:	10

Table 2. Results when the number of iterations is 10

Method's name	Initial number of penalty points	Final number of penalty points	Initial probability	Final probability
Bayes	1251	86	0.5	0.625
Exkor	1251	86	0.5	0.25
Globt	1251	83	0.5	0.63219
LBayes	1251	80	0.5	0.5
Mig1	1251	94	0.5	0.3897

All initial data remains unchanged, just the number of iteration is different.

Number of iterations: 5000

Table 3. Results when the number of iteration is 5000

Method's name	*Initial number of penalty points*	*Final number of penalty points*	*Initial probability*	*Final probability*
Bayes	*1251*	*65*	*0.5*	*0.68458*
Exkor	*1251*	*73*	*0.5*	*0.375*
Globt	*1251*	*72*	*0.5*	*0.13271*
LBayes	*1251*	*79*	*0.5*	*0.91168*
Mig1	*1251*	*69*	*0.5*	*0.50927*

Table 4. Results after thorough experiment with "Bayes" method

Method		**Task**	**Result**		
Name	**Number of iterations**	**How many times the problem was optimized?**	**Number of iteration**	***F(x)***	**Probability**
Bayes	**5000**	**2**	999	16.0	0.871
		6	999	10.0	0.625
		13	999	10.0	0.750
		25	999	8.0	0.500
		50	999	8.0	0.500
		100	999	8.0	0.500
	10	**2**	99	14.0	0.531
		6	99	13.0	0.250
		13	99	9.0	0.750
		25	99	14.0	0.438
		50	99	8.0	0.500
		100	99	8.0	0.500

Table 5. Results after thorough experiment with "LBayes" method

Method		**Task**	**Result**		
Name	**Number of iterations**	**How many times the problem was optimized?**	**Number of iteration**	***F(x)***	**Probability**
LBayes	**1000**	**2**	999	15.0	0.500
		6	999	13.0	0.500
		13	999	11.0	0.500
		25	999	8.0	0.500
		50	999	8.0	0.500
		100	999	8.0	0.500
	100	**2**	99	18.0	0.500
		6	99	18.0	0.500
		13	99	11.0	0.500
		25	99	8.0	0.500
		50	99	9.0	0.500
		100	99	8.0	0.500

6.3. The results obtained with various methods

In the first column of Tables 4 through 8 is the name of the method and the number of iterations are given. The second column – specifies the number of times the problem instance was optimized. The third column characterizes the result after optimization. The "Number of iteration" in the column "Result" is the iteration number that specifies in what time the best result was attained. Function *F(x)* characterize the best count of method (Bayes, LBayes, Mig1, Globt, Exkor) and shows the optimal part. "Probability" shows at which probability the value of the function *F(x)* was obtined.

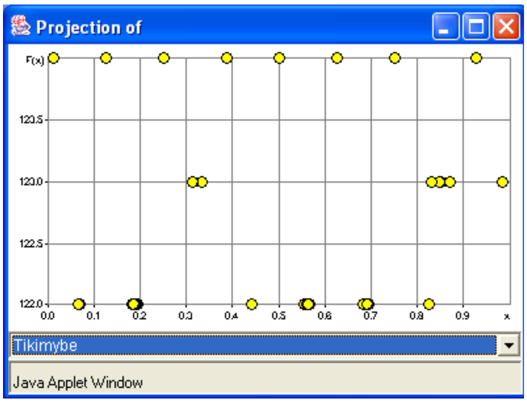


Figure 7. Dependence random variables of value in “Bayes” method

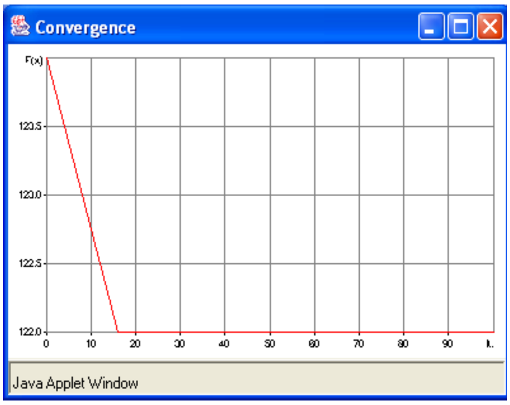


Figure 8. Variation of variable when the number of iteration is growing in “Bayes” method

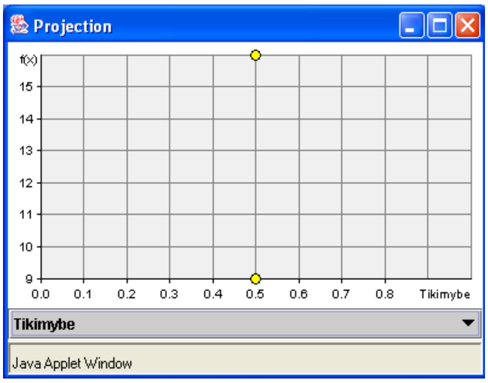


Figure 9. Dependence random variables of value in “LBayes” method

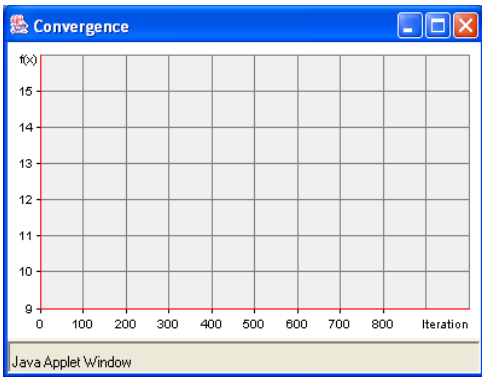


Figure 10. Variation of variable when the number of iteration is growing in “LBayes” method

Table 6. Results after thorough experiment with “Exkor” method

Method		**Task**	**Result**		
Name	**Number of iterations**	**How many times the problem was optimized?**	**Number of iteration**	***F(x)***	**Probability**
Exkor	**5000**	**2**	100	17.0	0.653
		6	100	20.0	0.327
		13	100	14.0	0.306
		25	100	18.0	0.265
		50	100	15.0	0.204
		100	100	11.0	0.122
	10	**2**	99	19.0	0.750
		6	99	17.0	0.345
		13	99	13.0	0.750
		25	99	10.0	0.500
		50	99	8.0	0.250
		100	99	8.0	0.250

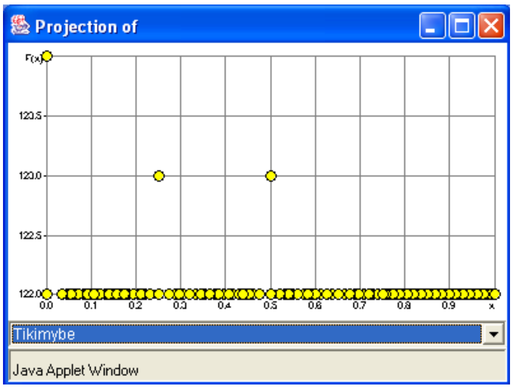


Figure 11. Dependence random variables of value in “Exkor” method

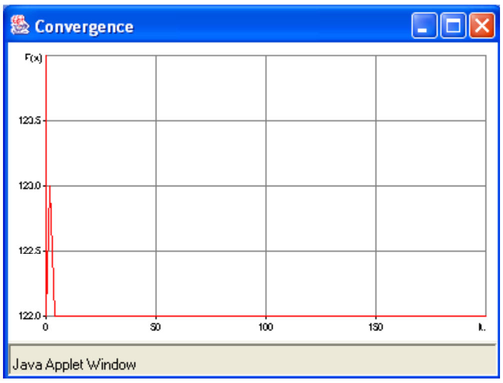


Figure 12. Variation of variable when the number of iteration is growing in “Exkor” method

Table 7. Results after thorough experiment with “Globt” method.

Method		Task	Result		
Name	**Number of iterations**	**How many times the problem was optimized?**	**Number of iteration**	***F(x)***	**Probability**
Globt	**5000**	**2**	999	16.0	0.744
		6	999	15.0	0.868
		13	999	8.0	0.721
		25	999	8.0	0.957
		50	999	8.0	0.351
		100	999	8.0	0.151
	10	**2**	99	13.0	0.016
		6	99	11.0	0.561
		13	99	13.0	0.668
		25	99	9.0	0.911
		50	99	9.0	0.191
		100	99	8.0	0.349

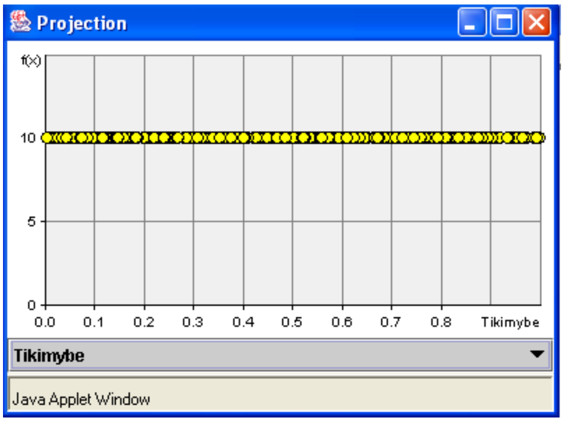


Figure 13. Dependence random variables of value in “Globt” method

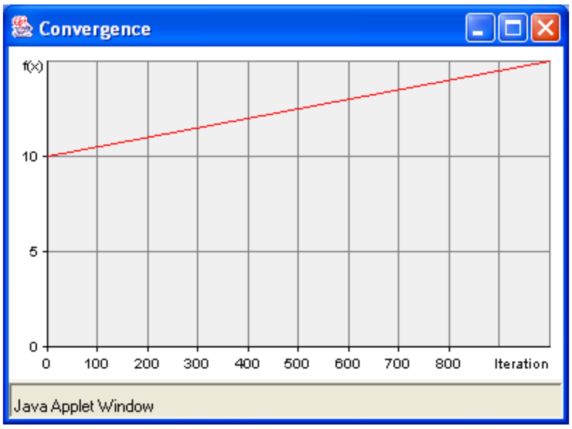


Figure 14. Variation of variable when the number of iteration is growing in “Globt” method

Table 8. Results after thorough experiment with “Mig1” method

Method		Task	Result		
Name	Number of iterations	How many times the problem was optimized?	Number of iteration	*F(x)*	Probability
Mig1	1000	2	999	17.0	0.393
		6	999	13.0	0.239
		13	999	15.0	0.833
		25	999	8.0	0.634
		50	999	9.0	0.656
		100	999	8.0	0.235
	100	2	99	17.0	0.779
		6	99	14.0	0.456
		13	99	13.0	0.692
		25	99	11.0	0.913
		50	99	8.0	0.326
		100	99	9.0	0.979

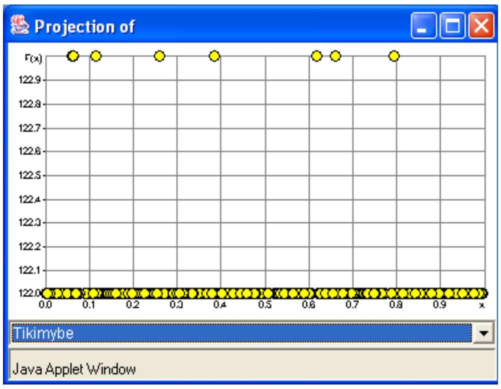


Figure 15. Dependence random variables of value in “Mig1” method

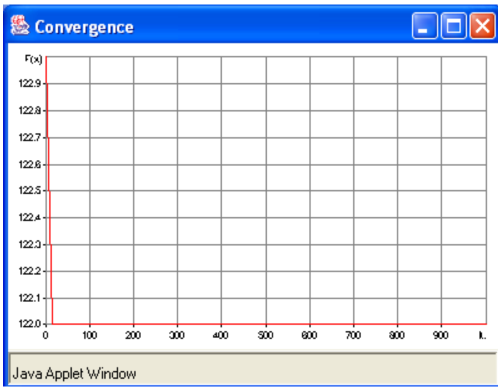


Figure 16. Variation of variable when the number of iteration is growing in “Mig1” method

6.4. A comparison with other programs

Table 9. Comparison of results obtained with the developed program with other programs

Name	The goal of program	The characteristic of the program	Initial data are:	OS under which the program works
„School schedule optimization program“	Making an optimal schedule	Has many optimization algorithms	Reading of initial data’s file;	Windows 2000/XP; Linux
„aSc Timetables 2003“		User must complete the schedule himself	Instructions from the user during runtime of the program	Windows 9x/2000/XP
„MIMOSA“	Performance all requests of the user			
„RECTOR“				

6.5. The advantages of program „School schedule optimization program“

We have revealed the following advantages of the developed program often comparing it with „MIMOSA“, „aSc Timetables 2003“and „RECTOR“:

- It does not require big skills or any computer knowledge and a lot of time to familiarize with the program. The user can easy apply this program. He must prepare just the initial data file.
- The optimal school schedule is good enough. It can be changed, when user sets other requests.
- The program produces an optimal school schedule very quickly, even if the personal computer and the internet is not fast. User must just set the initial requests.
- The user has a possibility to see all the names of lessons and his classrooms. The initial and optimal schedules are easy to read and informative.

7. Conclusions

After investigating another program we see that “MIMOSA“, “RECTOR” and “aSc Timetables 2003“ are not perfect for making schedules for profiled schools. This conclusion is supported by the fact that the user must not only put the initial data of schedule, but also set the lessons, teacher, or students manually. It is a very difficult process when the school is very big and has a lot of students and teachers.

The investigated program is designed in such a way that the user must make just a file of initial school schedule data and put the optimization request. The program forms and optimizes the schedule of the profiled school very well. If the user wants to make the changes, he can update the initial data file or change the optimization request.

References

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