

State Competitions in Informatics and the Supporting Online Learning and Contest Management System with Collaboration and Personalization Features MENDO

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Abstract. Macedonia has a tradition of organizing programming contests for high-school students as long as the tradition of IOI. In the last few years the organizer, the Computer Society of Macedonia (CSM), used the online learning and contest management system MENDO, firstly for the organization and carrying out of the national contests, and also for the promotion of the contests, programming and algorithmic thinking. CSM tries to provide a portal for the students that will offer complete learning materials and tools, and that will motivate them and allow them to learn programming and prepare for the competitions. In this paper we will present MENDO with its new features, and we will mention some new and original features for collaboration and personalization. At the end, we will present the great improvements in sense of the number of contestants and achievements of Macedonian students at the international competitions, showing that MENDO is a valuable asset for organization of competitions.

Key words: programming contests, collaboration, grading systems, automatic grading, contest management system.

1. Introduction

Competitions in informatics were introduced about forty years ago, with the idea of attracting talented young people to the science of computer programming. These competitions are usually synonyms for algorithmic programming contests (other types include architecture, design, development, specification, assembly, testing scenarios, etc).

Competitions in informatics have a long tradition in Macedonia. There were 23 national contest cycles till the end of 2012. After many competitions on national level, the best contestants represent themselves and Macedonia at the IOI – International Olympiad in Informatics, the BOI – Balkan Olympiad in Informatics (for high school students), and the JBOI – Junior Balkan Olympiad in Informatics (for primary school students).

Usually, these programming competitions require students to submit programs which are then run through a variety of test scenarios and judged accordingly. The difficulty, however, lays not so much in the programming but rather in the design of the underlying algorithms (Burton, 2008). More often than not, these contests are based on automatic grading of the submitted solutions. This is accomplished by running them on batches of input data and testing correctness of the output. Time and space limits are usually enforced during the process, which allows to judge not only by the (approximation of) correctness of the solution, but also by its time and space complexity, as explained in Mares (2007).

Besides the automatic grading capability, a contemporary programming contest system requires some other functionalities that would facilitate the preparation of the students for competitions, like some kind of a communication page (or a forum), a page for sharing appropriate learning materials, an info page, etc.

In this paper we present the system that supports the Macedonian competitions in informatics, named MENDO, along with its improvements during the last three years of its usage. The paper is organized as follows. In Section 2 we describe the format of the informatics competitions in Macedonia, their organizer, and the challenges we are facing. In Section 3 we present the need for contest management systems, and we mention the necessary building modules of such a system. Section 4 presents the architecture of our system MENDO, with the improvements from its first deployment until today. In this section significant specific realizations of some modules are explained. Additionally, some user oriented features of MENDO are explained including some unique ones for collaboration and personalization. Further, in Section 5 we present some results from the VI Junior Balkan Olympiad in Informatics, held in 2012 – a contest organized using MENDO. Finally, in Section 6, we present results from the use of MENDO in the Macedonian competitions in sense of the quality of the organization, the pupils' interest for the competitions, and most significantly the accomplished results in international competitions.

2. Competitions in Informatics in Macedonia

Competitions in informatics have been held in Macedonia since 1990. There were 23 national contest cycles till the end of 2012. Every year, the contestants go through many levels of competition in order for the best to be selected: Qualifications, Regional Competition, State Competition, Macedonian National Olympiad, and Preparations for international contests (sometimes including additional competitions). The selected pupils represent themselves and Macedonia at the BOI/JBOI and at the IOI. The main organizer of the competitions in informatics is the Computer Society of Macedonia (CSM).

2.1. Computer Society of Macedonia (CSM)

CSM was formed on an initiative of a group of professors at the Institute of Informatics, Faculty of Natural Science and Mathematics, at the University of Ss. Cyril and Methodius

in Skopje, in the year 2000. This organization continued with the activities previously performed by the former Mathematical and Computer Society of Macedonia (Jovanov, 2012).

CSM is one of the holders of the idea for affirmation of the informatics society in Macedonia. Members of this organization are computer science teachers in high schools and primary schools, information technologists, as well as professors and teaching assistants at the Faculties of the Universities in Macedonia.

Among the main goals of CSM are the following:

- introduction, popularization and promotion of informatics and information technology and its application;
- encouragement and introduction of informatics in all areas of the society, especially in the education;
- organization, implementation and participation in informatics competitions for pupils and students.

2.2. Format of the Macedonian Informatics Competitions

The first steps of informatics in high school education were made in the middle 1980s. A few years later, in 1990, the first State Competition in Informatics was held in Prilep. In 1993, CSM started to organize Regional Competitions in Informatics. The first Macedonian National Olympiad in Informatics was held in 1997. The competitions for primary school pupils began to be held in 2007. So far, CSM has organized 20 Regional Competitions, 23 State Competitions and 16 Macedonian National Olympiads for high school pupils, and 6 State Competitions for primary school pupils. (In Macedonia, Primary school consists of 9 grades, followed by obligatory Secondary school which can be gymnasium with 4 grades or vocational school with 3 or 4 grades).

At the beginning, in the first few competition years of the high school competitions, all the contestants were given only one set of programming tasks in each competition. Later, it was decided that it would be better to have the two groups of contestants solve sets of tasks with different degree of difficulty. So, the contestants were divided into two groups (named A and B), having a different set of tasks for each group (one set being more difficult than the other). After few years, a different naming convention for the contestant groups was introduced – from then on they were named ‘Easier group’ and ‘Harder group’.

The format of the competitions evolves every year, depending on many factors, such as the number of interested pupils, the inclusion of programming in the schools curricula etc. Presently, the competitions are organized for high school and primary school pupils, as follows. The contestants, depending on the level of acquired knowledge in the programming area, at the start of each contest cycle have to choose between:

- **Beginners group:** primary school pupils or high school pupils with no experience, usually in their first year of high school education, not older than 15 years on first of January, in the actual year (eligible to participate at JBOI).
- **Basic group:** first or second time contestants that consider themselves not to have enough experience to participate in international competitions.

- **Advanced group:** contestants that consider themselves to have enough experience to solve complex algorithmic problems and to participate in international competitions (BOI, IOI) .

All the competitions are entirely conducted through a system called MENDO.

2.3. Challenges in the Organization of the Competitions

The organizer of the informatics competitions in Macedonia, the Computer Society of Macedonia, is a non-government, non-profit organization. Hence, the organization of the competitions is based solely on sponsorships from companies, educational institutions (like the Faculty of Computer Science and Engineering in Skopje), and sporadically from donations based on application in some calls for projects. Having in mind the low finances, CSM has to find as cost-effective as possible way for the following:

- **Engaging pupils in the competitions** – We have to spread the information among the pupils and keep them informed. We have concluded that the best way to do that is to build and maintain a ‘community’ of competitors, and let them collaborate throughout the whole year. Of course, we also use some more traditional methods, e.g., contacting and informing the schools, contacting the computer science teachers, but there are obstacles in that regard too.
- **Motivating teachers and school authorities** – The most important thing (on this issue) is to motivate the teachers to inform and mentor the pupils. With years of our experience, we have found that the computer science teachers, mainly, do not want to spend extra time for tutoring gifted pupils and the greatest reason for this is that they are not familiar enough with the curriculum of the programming competitions. The best solution consists of two things: (1) Provide online materials, training and q/a support for the pupils, in every stage of their training for the competitions, and (2) Inform the teachers for this convenience and put additional pressure directly through the pupils. The school authorities can also be an obstacle for the participation of the pupils, mostly with ridiculous reason in mind like not spending money for the trip of the pupils to the contest venue. On this issue, we can only hope on the pressure of the pupils and the teachers on them.
- **Keeping the participants informed, and ‘in condition’** – We have to publically present the information for the next steps in the competitions (dates, rules, procedures, results, etc.) in order to directly inform the pupils, as we have concluded that this is the most reliable way to spread information (opposite to informing through the teachers and schools). The greatest challenge of all is to motivate pupils to constantly prepare (work on solving problems) for the competitions, with public sets of tasks that can be solved at any time.

During the last couple of years, some events and movements in the Macedonian society and worldwide have worked in our benefit, thus providing us with better conditions for fulfilling our goals. For example, we had a dramatic improvement in the area of internet penetration, and nowadays we have similar conditions for internet access as most EU countries. Also, the government project “Computer for every pupil” allowed easy access to internet content from every classroom.

3. Contest Management and Grading Systems

A contemporary programming contest system, besides the automatic grading capability also requires other functionalities that would facilitate the preparation of students for competitions. That is why it should be referred as contest management and grading system.

At the International Olympiads in Informatics, the use of a grading system is an absolute necessity. By comparison of the data presented in Manev (2009) with current observations from IOI competitions we can conclude that there was drastic improvement in the time-consumption of the grading process at different IOI competitions. The time for grading was reduced from couple of hours to only minutes, and at very recent IOI's, with the use of tokens, to almost zero time.

Historically, in Macedonia for example, a few separated systems (evaluation program, contest website, forum page called "Communication window", etc.) supported the organization of the competitions. However, a lot has changed since the first competitions – the computer equipment has improved, new information technologies have been introduced, and at the same time, the technique and technology of development and judging competition tasks has improved.

The best solution, from a practical point of view, certainly is to integrate all the required functionalities mentioned above in a single automated system for complete contest management. This system would provide all the necessary contents for the students to successfully prepare and participate in programming contests, as well as all the necessary capabilities for the organization of programming contests (including submission of tasks and automatic grading).

3.1. Present Contest Management Systems

There are few existing systems for contest management and grading. Examples include Mooshak, Moe, CMS, DOMjudge and PC². Today, however, we can talk about self managed systems that completely administer contests (including gathering and grading of submissions, managing competitor's questions and clarifications, publishing results, providing statistics, etc.). Some systems even offer a continuous on-line training process.

Whatever the system offers, it should be designed such that it is simple, robust, secure and flexible. According to our observations and the observations from several other authors, standard modules for almost all grading systems are:

- **Sandbox** – ensures that the execution of a submission will not harm the system or the host computer; enforces time, memory and network restrictions;
- **Grader** – does compilation of contestant solutions, management of the sandbox, comparison of user output to correct output, and grading of a submission;
- **Controller** – handles the communication with the judges and competitors, and executes database operations;
- **Auxiliary modules** – handle printing, backups, storage, etc.

4. Architecture and Other Features of MENDO

Here we describe the system called “MENDO”, which is currently used by the Macedonian Computer Society in the organization of national informatics competitions. This system was introduced in Kostadinov (2010). MENDO was developed following the goal of integration of all previously used modules’ functionalities in one compact environment: uploading of the competition tasks (organizers) and the solutions (contestants), evaluation and grading of the uploaded solutions, publishing results and communication. The acronym “MENDO” in the Macedonian language stands for “Macedonian Electronic Competitions and National Olympiads”, and as a word it means “teddy bear”.

4.1. Architectural Design and Technical Features

MENDO includes all the modules that are standard for contest management and grading systems. It works as a web application, so judges and competitors use browsers to communicate with the system.

The controller and grader are written in Java, and can be run on every popular operating system (like Windows and Linux). For database operations we use Hibernate and C3PO thread management to connect to a MySQL database and execute queries. There are two sandbox implementations: one for Windows and one for Linux. Besides the fact that only a small number of grading systems operate on Microsoft Windows, we found the operating system to be very stable, reliable and easily controllable. More details about the implementation of the sandbox are presented in Kostadinov (2010).

In our implementation, the auxiliary modules are part of the web application and are also written in Java and run on an Apache Tomcat server. Besides the main system, MENDO also contains a public forum and a wiki.

An important feature of MENDO is that it uses cookies to support SSO – Single Sign On across multiple applications (the main system, the wiki, and the forum). All applications are running on the same server. Since all subsystems use Single Sign On and automatic language detection, there is no need to change the language or login every time you switch from one subsystem to the other, since this is automatically done by the underlying system.

Other MENDO specific technical features can be summarized as follows:

- MENDO controls the entire system of the Computer Society of Macedonia, by providing automatic backups for itself and the other applications, self-tests of the application, the server and the operating system;
- The system has multilingual support (currently Macedonian and English, but we are planning to add more languages in the near future);
- MENDO is managed by several administrators and moderators, each with his own privileges and responsibilities. Every moderator and administrator can add tasks, create competitions, generate reports for each task and competition, and initiate system backups;
- The system easily distributes load. Plugging more graders is easy, thanks to the modular architectural design of the system;

- There is a heavy use of AJAX to simplify user interface operations (during registration, training sessions, competitions, etc). We use the jQuery 'write less – do more' javascript library to implement most of the event handling and AJAX operations.

4.2. Employment of MENDO

In practice, MENDO is used as:

- a training system (contains tasks from past contests, both national and international);
- a contest management system (for organizing official national competitions and open online tournaments);
- Macedonian algorithmic programming gateway, containing a news page, a lot of programming related materials (organized in a wiki), and a public forum.

4.3. MENDO as a Training System

Given the format of competitions, and especially the way of grading the solutions through test cases, the training system had to be able to provide the same kind of judging as real contest grading system. The main and simplest idea is to copy the real grading system, and use it in the training section.

The MENDO's training system *can be used 24/7* (a screenshot of the MENDO training section is shown in Fig. 1).

Every time a user logs in to MENDO's web-site, he can view all the tasks that are available for training, and he can submit a solution. After a solution has been submitted,

The screenshot shows the MENDO web interface. At the top, there is a logo of a bear and the text 'MENDO System for competitions in informatics 2013'. There are language selection buttons for 'English' and 'Македонски'. A navigation bar includes 'Home', 'Training', 'Competitions', and 'Help'. A status bar shows '89319 tested submissions | 3304 users'. The main content area is titled 'Learn programming...' and features a table of 'International programming contests'. The table has columns for 'Task name', 'Task source', 'Languages', and 'Success rate'. The user's profile information is visible on the left, including 'Username: mile', 'Country: Macedonia', and 'Activity: 1 solved tasks'. There are also buttons for 'Chat OFFLINE' and 'AI'.

	Task name	Task source	Languages	Success rate
1.	Map	jboi 2007	🇲🇰 🇲🇰	36/100 (36%)
2.	Books	jboi 2007	🇲🇰 🇲🇰	28/88 (31%)
3.	Numbers	jboi 2007	🇲🇰 🇲🇰	24/100 (24%)
4.	Boats	jboi 2007	🇲🇰 🇲🇰	8/36 (22%)
5.	Chairs	jboi 2007	🇲🇰 🇲🇰	26/67 (38%)
6.	Coins	jboi 2008	🇲🇰	20/49 (40%)
7.	Closest	jboi 2008	🇲🇰	4/40 (10%)
8.	Rectangles	jboi 2008	🇲🇰	20/46 (43%)
9.	Jumps	jboi 2008	🇲🇰	17/112 (15%)
10.	Squares	jboi 2008	🇲🇰	7/63 (11%)
11.	Sumx	jboi 2008	🇲🇰	25/154 (16%)
12.	Handshakes	jboi 2009	🇲🇰	8/65 (12%)
13.	Riddles	jboi 2009	🇲🇰	5/24 (20%)
14.	Crane	jboi 2009	🇲🇰	5/18 (27%)

Fig. 1. Screenshot of the MENDO training system – lists of tasks. Available online at <http://mendo.mk>

The screenshot shows the MENDO website interface. At the top, there is a navigation bar with 'Home', 'Training', 'Competitions', and 'Help'. The user is logged in as 'mile' from 'Macedonia' and has solved 1 task. The main content area is titled 'Learn programming...' and features a table of lessons for 'The C++ programming language'. The table lists 14 lessons, each with a name, source, and activity type.

	Name	Source	Activity
1.	Вовед. Структурирано програмирање		lecture
2.	Бинарен броен систем		lecture
3.	Типови на програмски јазици		lecture
4.	Креирање на вашата прва програма		lecture
5.	Анализа на првата програма		lecture
6.	Здраво	вовед '12	task
7.	Податочни типови. Променливи		lecture
8.	Читање и печатење на податоци		lecture
9.	Оператори - прв дел		lecture
10.	Квадрат и куб	оператори	task
11.	Математика	оператори	task
12.	Средна цифра	оператори	task
13.	Оператори - втор дел		lecture
14.	Условно извршување (if-else, switch)		lecture

Fig. 2. Screenshot of the MENDO training system – training lessons section.

the submission is added to a queue and judged as early as possible (the time slot is no longer than 1 minute, even during heavy-load competitions).

After a submission has been judged, the results of every test case are shown to the user in a form called detailed feedback. There is no limit to the number of submissions a user can make during a time period, but the system does support a couple of defensive mechanisms to prevent Denial of Service attacks.

MENDO also offers a special section consisting of organized materials that present an online step by step introduction to algorithmic problem solving and programming (with C++ as the programming language). This feature offers a number of lessons, combined with executable sample codes and proposed tasks connected to the information presented in the lesson in question (Fig. 2). Every user has a personal view of the lessons, showing her current progress.

4.4. Specific MENDO Features

As a system designed to support learning, MENDO has a few unique features that help students prepare for national and international competitions in informatics. We will present a couple of them: the ability to detect simple mistakes, downloading test cases and virtual contests.

Simple analysis of the source code – When a student submits a solution to a task (for example, a task from a previous national competition – available in training), the system automatically analyses the program output and the source code of the uploaded solution. If a simple mistake of not following specific rules is detected (printing additional data,

using commands like `system("pause")`, writing to files instead of standard input/output, etc.), the system notifies the user that he has made a mistake that can be easily fixed and it provides to the user details about the mistake.

Downloading a test case in training mode – After a student submits a wrong solution to a task, he is presented with an option of potentially downloading one of the test cases that his solution does not correctly solve. Users are limited in the number of tests that they can download in a certain time period. We have found this to be a very positive change in the system and a lot of users are taking advantage of this feature to fix mistakes in their code instead of just giving up on solving a problem.

Virtual contest – The third option that we believe is very important (as a personalization feature) is the possibility to create virtual contests. Virtual contest is contest that is created on a user request and is based on the user's performance history in training section of the system (solving various tasks) and previous competitions. It is actually a simulation of a contest, seen only by the user that demanded it.

In the beginning, the system automatically determines the "best" tasks that should be included in the contest, from the set of tasks existing on the system. After the contest (the time period given to the contestant to solve the proposed tasks) the system automatically presents to the user a virtual scoreboard. The scoreboard consist names of other contestants, and the most important information on it is the ranking of the contestant that took the contest. The scoreboard is fictional but it is based on various system information from other actual competitions (the ones where the chosen tasks were included), and also the solvability of the tasks in the training section, etc.

Additional test case options – We have considered even more ideas with test cases. Some of them, explained in Jovanov (2011) are:

- **Including hint(s) for a test case.** This requires the problem maker to provide some kind of hint (or hints) for every test case for the program. This slows the process of task preparation, because it requires an additional effort. Nevertheless, when producing test cases, the problem maker almost always has in mind what part of the task (i.e., of the solution) is checked by each particular test case. The additional effort will be to put that in form of a hint, for the contestants that will use the task in the training section.
- **Hint for a test case by a competitor** – Following the previous idea and putting in force the full potential of the human – computer collaboration, the next step is to allow a user who has solved some particular test case of the problem, to provide a hint for that test case. There is more work to be done on determining (grading) the quality of the hint, depending on the user that provides it.
- **Complete test case by a competitor** – A competitor that has solved the problem could be allowed to provide a test case, that she believes is essential when grading the solutions. In this way, the system will gain better set of test cases for testing the subsequent submissions.

One other feature that is worth mentioning here is the ability of the system to produce reports and statistics. After the grading of each competition, the results are automatically published (this can be disabled, if necessary), and a report is generated. This report contains details and statistics for every competitor, every programming language, every task

and even every test case that is part of that competition. The numbers can be presented in different formats.

5. MENDO's Employment in JBOI 2012

As a contest management system, we have used MENDO in the 2010, 2011, 2012 and 2013 contest cycles (more than 35 competitions, including both online and onsite rounds), and the system has proved to be quite stable, fast and robust. MENDO has also been used as the official contest system at the XVIII Balkan Olympiad in Informatics held in Petrovac Montenegro (2010), and at the VI Junior Balkan Olympiad in Informatics held in Ohrid, Macedonia (2012).

The members of the Scientific Committee of JBOI 2012 were familiarized with all the features that MENDO offers, and having them in mind they prepared valuable sets of tasks for each of the competition days (For example, the sets included tasks with detailed feedback). These sets produced very good distribution of scores in both competition days and overall, as presented in Fig. 3.

Although the system used was not the only and main reason for the presented results, it certainly had a significant impact on them.

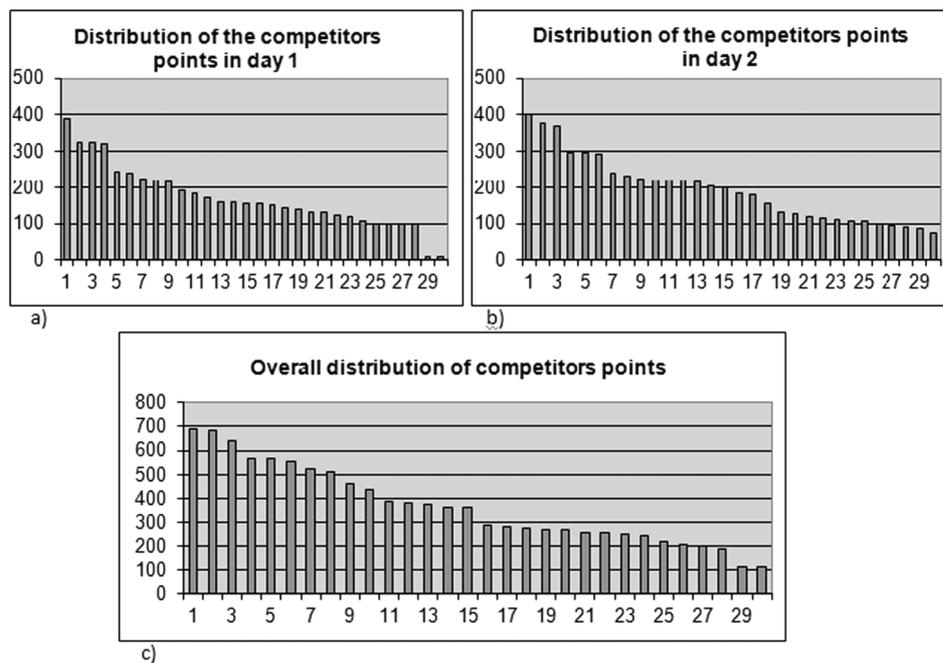


Fig. 3. Distribution of points scored by the competitors at the VI Junior Balkan Olympiad in Informatics 2012: (a) distribution in the first competition day (MIN = 10, MAX = 390, AVG = 166 out of 400 points), (b) distribution in the second competition day (MIN = 75, MAX = 400, AVG = 191,5 out of 400 points), (c) overall distribution (MIN = 115, MAX = 693, AVG = 357,6 out of 800 points).

6. Macedonian Competitions and Results of Macedonian Teams at International Contests since the Introduction of MENDO

We have introduced MENDO as a competition system in the 21st cycle of the Macedonian competitions in informatics (year 2010). Table 1 shows the number of participating contestants throughout the last five national contest cycles.

As can be seen from the first row of the table, the number of contestants in the Regional Competition (which is the most realistic indicator of the pupils' interest in the competitions since this is the starting point of the contest cycle where all the pupils that applied can participate), after the years of stagnation till 2010, grows rapidly from year to year. This means that one of the goals of CSM has been accomplished with the help of MENDO.

As we mentioned earlier, the best pupils at national competitions enter into the teams that represent Macedonia at IOI, BOI and JBOI. Macedonia has participated at almost each of the 24 IOI contests, 20 BOI contests, and 6 JBOI contests. The Macedonian pupils have won 19 medals in total at the 20 BOIs held so far. 9 of the medals have been won in the last 3 years. Moreover, pupils have won 10 medals in total at the 24 IOIs held so far, with 5 of them in the last 3 years. At the 6 JBOIs held till now, we have won 10 medals, 9 of which have been in the last 3 years. In Fig. 4 we can see the progress at the international competitions since the introduction of MENDO.

Starting with just 1 medal (in total at the 3 contests), we have reached a number of 9 medals in the last year (2012). Based on the opinions of the members of the organiza-

Table 1
Interest in the competitions in informatics in Macedonia
(expressed through the number of participating contestants)

Competition	Year				
	2009	2010	2011	2012	2013
Regional competition	51	55	118	209	290
State competition	44	45	68	95	118
Macedonian National Olympiad	22	23	19	21	21

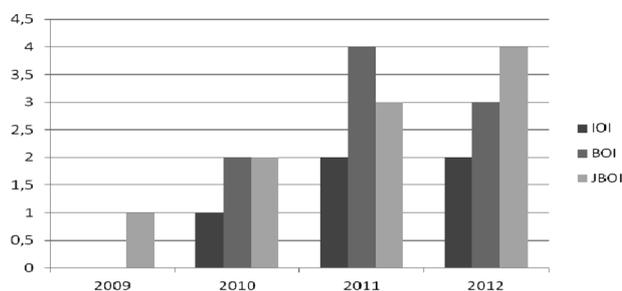


Fig. 4. Number of medals won at IOI, BOI and JBOI in the last 4 years.

tional and scientific committees, authors of the paper strongly believe that the MENDO system has played a major role in the presented progress.

7. Conclusion

In this paper we presented the format of the informatics competitions in Macedonia, the challenges of the organization and MENDO – the supporting system of the Macedonian competitions in informatics, with all the improvements during the last three years of its use. In the last sections we presented some results from a Balkan Olympiad in Informatics that used the MENDO system, as well as the results from its use in Macedonian competitions. The results are in favor of the system, in sense of the improvement of the quality of the contests through the number of additional features offered. Most importantly, MENDO plays an important role in the impressive improvement of the results of the Macedonian teams at international contests, as presented.

Using this system, or including the presented features in some similar system, can improve the quality of the contests and the whole process of training and elections of students for international competitions in most of the countries.

We constantly make enhancement to the system, and experiment with new ideas for improvements.

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