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Baltic Olympiads in Informatics: Challenges for Training Together

Timo PORANEN[a] *, Valentina DAGIENĖ[b], Åsmund ELDHUSET[c], Heikki HYYRÖ[a], Marcin KUBICA[d], Antti LAAKSONEN[e], Mārtiņš OPMANIS[f], Wolfgang POHL[g], Jūratė SKŪPIENĖ[b], Pär SÖDERHJELM[h], Ahto TRUU[i]

[a] *Department of Computer Sciences, University of Tampere*
Kanslerinrinne 1 FIN-33014 Tampere, Finland
e-mail: {tp, helmu}@cs.uta.fi
[b] *Informatics Methodology Department, Institute of Mathematics and Informatics*
Akademijos str. 4, Vilnius, LT-08663 Lithuania
e-mail: {dagiene,jurate}@ktl.mii.lt
[c] *Department of Computer and Information Science*
Norwegian University of Science and Technology
e-mail: asmunde@stud.ntnu.no
[d] *Institute of Informatics, Warsaw University, Poland*
e-mail: kubica@mimuw.edu.pl
[e] *Department of Computer Science, University of Helsinki, PL 68, 00014*
e-mail: antti.laaksonen@mbnet.fi
[f] *Institute of Mathematics and Informatics of University of Latvia*
e-mail: martins.opmanis@lumii.lv
[g] *Bundeswettbewerb Informatik*
Ahrstr. 45 53175 Bonn, Germany
e-mail: pohl@bwinf.de
[h] *Department of Theoretical Chemistry Lund University*
P.O.B. 124, SE-22100 Lund, Sweden
e-mail: par.soderhjelm@teokem.lu.se
[i] *TÜ Teaduskool*
Tähe 4-143, 51010 Tartu, Estonia
e-mail: ahto.truu@ut.ee

Abstract. Baltic Olympiad in Informatics (BOI[1]) is an annual informatics competition established by the three Baltic countries Estonia, Latvia and Lithuania in 1995 for upper secondary school students. BOI was later expanded to include all countries located around the Baltic Sea. One of the main goals of the BOI is to bring gifted students together and let them gain experience from an international event before participating in the International Olympiad in Informatics. Another important goal is to bring together the team leaders from different countries and to share their experience by creating common tasks. All tasks are developed and discussed as well as translated

*Corresponding author

[1] BOI is also used as abbreviation for the Balkan Olympiad in Informatics. Within this article, BOI refers only to the Baltic Olympiad.

before the BOI event using online facilities. The paper reviews some parts of the history of the BOI and gives a short glance at the current state of informatics education in the BOI countries. The main attention is focused on the task preparation process as well as presentation and analysis of statistical data from the previous BOI. Finally some development ideas and discussion on the future of the BOI competition are presented.

Keywords: olympiads in informatics, programming competitions, training, task categories.

1. Introduction

One of the most important parts of teaching cognitive skills is the teaching of problem solving (Dagienė and Skūpienė, 2004). Computer programming is one of the modern ways to develop problem solving skills. It may be argued that competitions make teaching of programming more attractive (Verhoeff, 1997). Students that learn basics of programming, soon start to look for opportunities to demonstrate their skills, use distance learning tools like UVA Online Judge[2], share their interests and compare themselves with others. For such students, one of the most effective means to endorse their motivation are the competitions. Competitions allow the students to meet their like-minded peers from all over their home-country as well as from other countries and to build friendships. They may eagerly wait for the next competition, ready to show how their abilities have improved since the previous competitions.

In order to ensure better preparation for the International Olympiad in Informatics (IOI) and to strengthen regional relations, various regional olympiads are organised (e.g., African, Central European, Baltic and Balkan Olympiads). While national olympiads represent informatics teaching traditions of each country, regional olympiads are usually a mini-model of the IOI, allowing participants to experience what they will face in the IOI (Blonskis and Dagienė, 2006).

The main goals of the Baltic Olympiad in Informatics (BOI) are to bring together gifted students, help them to share their scientific and cultural experiences and to provide participating students with the experience of an international competition. Further important goals are to bring together the team leaders from different countries, allowing them to share their experience, e.g., by creating common tasks. Moreover, the BOI is integrated into the IOI team selection process of some of the participating countries, allowing them to take into account the students' results in a competition similar to the IOI. The competition gives the contestants an experience of an international event before they participate in the International Olympiad in Informatics. The participants of the BOI are upper secondary school students interested in the field of informatics and computer science from a maximum of nine countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, and Sweden) around the Baltic Sea.

[2]Project "Integrating On-line Judge into effective e-learning" (UVa Online Judge) which has been funded with support from the European Commission under the grant number 135221-LLP-1-2007-1-ES-KA3-KA3MP helped in preparing this article.

In Section 2, we give a historical overview of the BOI. In Section 3, we explain how informatics is taught in the BOI countries. In Section 4, we describe how a BOI is organised, and in Section 5 we analyse tasks and solutions of the BOI 2007. The last section discusses our findings and gives ideas to improve organisation of regional contests in future.

2. History of the Baltic Olympiad in Informatics

The International Olympiad in Informatics (IOI) started in 1989. Soon first ideas about creating a regional contest for the Baltic countries emerged. In IOI 1991 in Greece, Håkan Strömberg (Nurmi, 2008) from Sweden proposed to organise a practice contest where all Scandinavian countries or at least Finland and Sweden could participate. However this plan was given up.

With the re-establishment of Estonia's, Latvia's and Lithuania's independence and their official recognition by the international community, teams from Estonia, Latvia and Lithuania were invited to participate in the Fourth International Olympiad in Informatics, which took place in Bonn (Germany) in 1992. At a glass of German beer, the delegation leaders of the three countries (Rein Prank and Indrek Jentson from Estonia, Māris Vītinš and Viesturs Vēzis from Latvia, Gintautas Grigas and Viktoras Dagys from Lithuania) had a discussion on how to help their students to prepare better for the International Olympiad. It was suggested that a common contest of the three countries could help in selecting the four strongest students from each country to participate in the IOI. The discussion about the Baltic Olympiads was continued at the two following IOIs in Mendoza (1993) and in Stockholm (1994).

The First Baltic Olympiad in Informatics took place in Tartu (Estonia), 21–23 April 1995. Following the standards of the IOI, it was agreed that the competitors of the Baltic Olympiad in Informatics would have to solve six problems during two competition days. The delegation of each country would consist of eight participants and two team leaders. Why eight competitors? With a team of eight competitors, team leaders were left with both sufficient choice in selecting their IOI team and the option to include younger students, who would probably join the national team in a year or two, for training purposes. The delegation leaders from each country had to propose three problems in advance, discuss them through electronic mail and select the six competition tasks from all the offered problems; translate them into the local languages after final approval and bring the translated tasks to the olympiad in printed form.

The integrity of the goals of the olympiad and mutual trust of the delegation leaders made it possible to organise a relatively short (3–4 days) and inexpensive event. Naturally, a week-long IOI is a real festivity for the contestants and their delegation leaders, which remains in their memory for challenging problems, new friends and interesting excursions. The Baltic Olympiad in Informatics (BOI), however, can be distinguished from the IOI by cosy and neighbourly atmosphere.

The second BOI was organised in Riga (Latvia) in 1996. Due to financial problems, the number of competitors in each team was decreased to six. The third BOI took place in Vilnius (Lithuania). While the first two olympiads were a good start for BOI, the first guest, Poland, was invited to the third olympiad in 1997. In 1998 the host country (Estonia) continued the new tradition of inviting neighbouring countries as guests and asked Finland and Sweden to join the BOI in Tartu. In 1999 Latvia invited Finland, Sweden, Poland and USA as guests. However, this was the time to reconsider the concept of member and guest countries. Sweden proposed to host BOI in 2000 and at this time the participating countries from around the Baltic Sea became member countries. Germany was the last Baltic see country to join the Baltic Olympiad in 2001 in Poland. Friendly relationships with Norway made her a permanent participant of BOI. The host countries still maintain the tradition of inviting guests to BOI (e.g., Israel was invited to BOI in 2005 and Switzerland participated in BOI in 2008). The current BOI member countries are Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, and Sweden.

The organisation of BOI has changed over the years. To keep the event manageable, the number of contestants per team was decreased to 6. The team leaders propose and discuss the tasks in advance, but now each country is asked to submit at least one task proposal (with 9 participating countries there is no more need for each country to come up with three proposals). Even though the tasks are decided in advance, the final formulation is approved during BOI. Modern contest and grading systems are used to manage the contest. The neighbourly help of countries with more experience of managing contests to host countries with less or no experience makes it possible to host well organised contests in all countries.

3. Informatics Education in the Baltic Sea Countries

In all the Baltic Sea countries, topics of informatics (software usage, programming, etc.) are taught in different ways and using various approaches. In Estonia, Finland, Norway, and Sweden software tool usage is integrated to other school subjects, but in Latvia, Lithuania, and Poland secondary schools have some elements of informatics education as separate subjects or modules. Table 1 summarises the current state of informatics education in the Baltic Sea countries' school systems. The first and second columns show the name of the country and its population, respectively. The last column gives an overview of the informatics education in the corresponding country.

In the following eight subsections we give a brief overview of informatics education and the BOI team selection in some of the participating countries

3.1. *Estonia*

In Estonia, three years of primary and six years of elementary school are mandatory for everyone. After that, pupils normally elect to attend either a gymnasium or a vocational school. A gymnasium means another three years of general education, with the prospect to go on to an institution of higher education upon graduation. A vocational school typically takes four years to give a profession in addition to a secondary education. In theory,

Table 1

Informatics education in primary and secondary schools in the Baltic Sea countries

Country	Pop. (mill.)	Informatics education
Denmark	5.4	Included in the subjects in high schools.
Estonia	1.3	Nominally integrated to other subjects. Many schools still choose to teach IT as a separate subject.
Finland	5.4	Integrated to other school subjects. Optional subject in some schools.
Germany	82.5	The situation of education in informatics varies widely between 16 states. In a few states, informatics is a mandatory subject in grades 6 or 8. More often, informatics is an optional subject in grades 9–10 and in most states it is an optional subject in grades 11–13.
Latvia	2.3	In grades 5–7 in primary schools, in secondary schools and gymnasiums informatics is a mandatory subject.
Lithuania	3.4	Information Technology is a mandatory subject in lower secondary levels starting from 5th grade to 10th. Informatics is one of the optional modules in grade 10 as well as in upper secondary levels, grades 11 and 12.
Norway	4.8	Integrated to other subjects. A mandatory technology course including some informatics is coming to the upper level. In some high schools, informatics is an optional subject.
Poland	38.1	Mandatory in all levels, starting from 4th grade.
Sweden	8.9	Integrated to other subjects. In secondary schools, informatics is a separate subject.

it is possible to enter a university after graduating from a vocational school, but in practice it is perhaps a bit more common to go to a vocational school for one and a half to two years to acquire a profession after graduating from a gymnasium and failing to get into a university.

Mastery of information technologies is recognised as an important skill in the national curriculum, but nonetheless informatics (or computer science) is not a separate subject. Instead, pupils are supposed to acquire the necessary skills in the process of using computers to learn other subjects. Schools are allowed, but not required, to offer informatics as a separate course and many schools do so. The curriculum only defines in general terms the ICT skills graduates of comprehensive schools should possess. These requirements describe the usage of computers as tools to create presentations, search for information and perform minimal statistical analysis (compute averages and create diagrams), but no topics usually associated with computer science. Also, no centrally approved text books, lecture plans, or other teaching materials are provided, and schools are expected to make their own decisions. Only a few schools offer computer science or programming classes either as part of a specialisation or in the form of an extracurricular activity.

A national olympiad in informatics has been organised (and supported by the Ministry of Education) since 1988 (with the exception of the year 1991). The participation in the preliminary rounds has ranged from 50 to 150 pupils, with the 30–40 best invited to the national finals. Out of those, 15–20 are further invited to training camps to select the teams for the international competitions. The camps take place on weekends.

Estonia has participated in the IOI since 1992, in the BOI since 1995, and a few times in the Central European Olympiad in Informatics (CEOI) as a guest country. Since the beginning, the main goal of participating in the BOI has been to give an international experience to the members of the future IOI team. Also, the BOI serves as the last selection round to pick the four IOI team members out of the six or eight BOI team members and usually the IOI team is announced immediately after the BOI.

3.2. *Finland*

In Finland, pupils usually start a voluntary one-year long pre-school when they are six years old, and after that, they attend the compulsory primary schools. Comprehensive school takes a total of nine years and is divided into a lower level (grades 1–6) and an upper level (grades 7–9). After comprehensive school, the two main options to study further are vocational and upper secondary schools.

In the lower level, informatics education is integrated to other school subjects, like Finnish language and literature (information searching, writing with technical tools) and mathematics (logical thinking, combinatorics, etc.). Only in the upper level and in the upper secondary school it is possible in some schools to study information technology as an optional subject. A drawback of the Finnish informatics education system is that the quality and content of teaching depends highly on the particular school's resources and the teacher's own activity, skills and knowledge. There is no general syllabus.

The Finnish national informatics competition for school students (called "Datatähti" which literally means "Data Star“) consists of two stages. The first is an open on-line stage, where the students have 2 weeks time and send their solutions by email. Roughly 15 best students are invited to the second and final stage, which is organised on-site. As an incentive to participate, the top 10 competitors are granted a free entry (i.e., without having to take an entry exam) to most universities in Finland. Based on the results, about 8–15 best students are selected to the IOI training. These students receive learning material and monthly programming tasks by email, and they also participate in a training camp, usually organised in late March or early April. Finland's BOI team is selected based on the results of the national competition as well as the level of achievements during training (both email tasks and the training camp). In 2008, 33 students participated in the first round of the national competition. This may seem low, but it is in fact the second highest number since the year 2002. The main reason for joining the BOI was to provide a good practice opportunity for Finland's IOI team.

3.3. *Germany*

In Germany, school education is supervised by the 16 federal states. Each state has its own rules and administration for the school system, so that, in fact, there are 16 different school systems in Germany. In the following, the more or less typical case will be described, if not stated otherwise.

Children enter school at the age of six. After four years of primary school, there are mainly three options for secondary school (that is the official term in Germany; in other countries, “elementary” is used instead). One of them is the “Gymnasium” that takes eight years to prepare children for academic education. The other school types take six years to prepare for a vocational education. Vocational education is then done in a so-called “dual” way: practical aspects are learned within one company, more theoretical aspects in vocational schools.

For informatics education, the situation varies widely among the 16 states. In 2007, a bachelor thesis investigated the situation in detail (Weeger, 2007). In almost all states, a basic “IT education” of using IT systems is integrated into other subjects within secondary education. In most states, informatics is an optional subject, but in only two states, informatics is compulsory for all students (in three other states, individual schools may decide to make informatics compulsory for their students). The amount of teaching is about 1 hour per week.

“Bundeswettbewerb Informatik” (Federal Contest in Informatics; BWINF) was founded in 1980; since 1985, it is organised annually. According to the dimensions presented by Pohl (2006, 2007), BWINF is a long-time (homework) task contest, with mixed submission of executable programs (all programming languages are allowed, except assembler and machine language) and solution descriptions, and with manual grading of submissions. Tasks cover many aspects of informatics; there are no age or other divisions. Hence, BWINF differs a lot from olympiad-style short-time task contests, with automatic grading of source code submissions.

BWINF takes a year, its finals take place in autumn (September or October). In the following year, about 12 BWINF finalists enter the process of preparing and selecting the German IOI team, together with a few participants from another competition. After two training camps (each 2–3 days long), the number of IOI candidates is reduced to about half. Traditionally, the IOI team is then selected based on performance in a third training camp (5 days). Recently, performance at the BOI has more and more often determined the IOI team selection.

Germany has participated in the IOI since the beginning in 1989. Since 1997, a German delegation has taken part in the Central European Olympiad in Informatics (CEOI; in 2000 Germany became full CEOI member). Since 2001, Germany also sends a delegation to the BOI. Since the CEOI takes place in early summer, usually about a month or two before the IOI, Germany sends its IOI team to the CEOI in order to bridge the training gap between the BOI and the IOI.

3.4. *Latvia*

Basic education is almost the same as in Estonia. In the grades 5–7 there is a mandatory course of informatics. In grades 8–9 there is no separate subject but informatics is integrated in other subjects. Topics like text and image processing, spreadsheets, preparation of presentations, work with files and Internet are discussed.

In secondary schools and gymnasiums informatics is a mandatory subject. In addition to deeper investigation of already taught themes also databases and preparation of web pages are added. In last years there is also the possibility to teach separate subject “programming” which is chosen by specialised schools and gymnasiums. Secondary school standard is closely integrated with the European Computer Dricing License (ECDL) and successful passing of school course gives possibility to obtain also the ECDL certificate.

Olympiads in informatics in Latvia are organised since 1986 and since 1988 they are supported and conducted by the Ministry of Education and Science. During the last few years, the national olympiad is organised in two groups (grades 8–10 and 11–12). There are three rounds: optional school round, regional round (approx. 100 contestants in each group) and final round (40–45 contestants in each group). After the final round there is a special selection round for participation in the BOI where the best 20 from both groups compete for a place in the BOI team – the best of the selection round are included in the team. The best four according to the BOI results are included in the IOI team. Latvia has participated in the IOI since 1992. It is one of the three co-founders of the BOI.

3.5. *Lithuania*

The Lithuanian school education mainly consists of three stages: elementary (grades 1–4), basic or lower secondary (grades 5–10) and upper secondary (grades 11–12). Full-time education is compulsory for all children from the age 6 or 7 to 16.

The teaching of informatics has a long tradition (Dagienė and Skūpienė, 2007) in Lithuanian schools; a rich experience in the field has been accumulated. The education programme of lower secondary schools, starting with the fifth grade, includes a separate course on IT, a part of which will be integrated with other subjects in future. A total of 68 hours in grades 5–6 are devoted to a course on IT. Thirty-four compulsory hours and 68 integrated hours for IT are suggested in the course designated for grades 7–8.

A course on IT in grades 9–10 is aimed at summarising and systematising students' knowledge as well as at purposeful usage of their skills, drawing attention to the right application of the technologies and their legitimacy. For those who wish to grasp the principles of computer work and its management, an optional module on algorithms shall be proposed (at the moment it is included in a compulsory IT course). For the course on IT in grades 9–10, 34 obligatory hours, 17 optional hours and 17 integrated hours are recommended.

An IT course for upper secondary grades 10–12 is being essentially revised. Several optional modules mostly oriented to the requirements for study courses in higher educational institutions are being developed. The content of IT is directed towards the trends of information technology usage and training in this field in other European countries. Developing algorithms and programming is one of the optional modules.

Lithuania was among the three Baltic countries to initiate the first BOI. The BOI team is selected among the 30 senior division finalists of the national competition. The main criteria are the scores of the finals, former achievements (BOI, IOI medals) and the age. As students of the three last grades (10 to 12) participate in the senior division, the students from younger grades have priority against older students if their scores in the finals are almost equal.

Only the participants of the BOI compete for the right to join the IOI team. In rare cases it happens that there is no fair way to choose exactly six contestants to the BOI. In that case the extra contestants solve the BOI tasks in Lithuania at the same time as the BOI contestants thus taking part in competition to join the IOI team. IOI team is selected on the basis of the BOI results and (as they might also be approximately equal) taking into account former achievements, scores of national finals and the age.

The time gap between the national finals and the BOI typically is very small (sometimes less than a week) so the competitors have no training camps for the BOI. There is only one week-long training camp in summer before the IOI. Taking part in the BOI is highly important for the IOI contestants. The students know how to compete at home or in the training camp, but when they come to an international event, they have to adjust themselves mentally, sometimes failing to do so because of psychological reasons rather than because of difficult tasks, especially if the IOI is in a distant country. Adjustment process is not always easy, and the BOI with small and cosy community, but at the same time international atmosphere serves great for that purpose.

3.6. *Norway*

In Norway, pupils enter school the year they turn 6 (after a voluntary one-year preschool). Comprehensive school is divided into a lower level (grades 1 to 7) and an upper level (grades 8 to 10). Afterwards, pupils may choose to enter either a four-year vocational school or a three-year theoretical high school (for preparing for university studies in science, economics or humanities). While high school is voluntary, almost everyone enters one of the two types. Unfortunately, informatics is an underrepresented subject. In comprehensive school, one gets superficial introduction to the basic usage of computers through other courses; there is no course dedicated to computers. However, a new course entitled "Technology and design" has recently been introduced to upper-level comprehensive school, and this may offer new opportunities for exposing pupils to informatics. The theoretical high school has a mandatory course in "information management" which mostly consists of learning how to use Microsoft Office. Some high schools offer more advanced courses that include lightweight database usage with Microsoft Access and possibly macros/scripting with Visual Basic for Applications. However, this does not touch upon any theoretical aspects of computing.

The Norwegian Olympiad in Informatics (NIO) started in 2000/2001. It is formally hosted by the Norwegian University of Science and Technology (NTNU), but is run by a practically independent group of volunteers consisting mostly of students who are former IOI contestants. Due to the small number of people organising the NIO, difficulties with acquiring funding, and the lack of informatics education, there are problems reaching out to the high school pupils. Therefore, the number of participants has always been very low – typically between five and fifteen. Recently, the university has become more willing to sponsor NIO, so that the attendance is expected to increase.

There is only one qualification round. Four tasks of varying difficulty (one of them is very simple and one is at least at the BOI/IOI level) are published on web page, and are available there for a period of around three months, during which anyone who is interested may solve the tasks. They then submit solutions consisting of source code as well as code documentation, algorithm descriptions and proofs of correctness. Points are awarded for each of these categories. Up to the 30 best participants are invited to the onsite finals at NTNU. Due to the low number of contestants, there is no need to use the BOI as a second elimination round. So, the four best contestants from the finals are invited to both the BOI and the IOI. The team that is sent to the BOI is normally a subset of the IOI team – regrettably, the BOI often collides with the high school spring exams, causing some of the pupils to decline to participate. There is no formal training programme (again due to the limited capacity of the organisers), but the participants are urged to solve selected tasks from earlier BOIs and IOIs, and to participate in a week-long national computer science camp called CyberCamp (there is significant overlap between the NIO and CyberCamp, both on the participating and the organising side).

3.7. *Poland*

Children in Poland start their education at the age of 6 with a one-year pre-school course, which is followed by six years of primary school, three years of a gymnasium and 3 or 4 years of a secondary school. Education of, so called, informatics starts in the 4th grade and continues in the gymnasium and the secondary school. However, children rather learn how to use information technology and software tools. Real informatics, including programming, is taught in some secondary schools. As a result, most of the contestants of the Polish Olympiad in Informatics (POI) are autodidacts. On the other hand, a few leading secondary schools have very strong representation in the POI every year – all thanks to active and competent teachers of informatics. Many efforts to improve education of informatics in Poland focus on training of teachers.

The POI (Diks *et al.*, 2007) also tries to influence and improve the education of informatics in Poland. Obviously, the human resources to work directly with all the pupils or teachers are not sufficient. The educational activities are twofold. Firstly, to provide various educational materials: handbooks, task sets, open contest servers, etc. Secondly, to train as many top contestants and their teachers as possible. The biggest such event is a summer training camp for teachers of informatics and POI finalists (excluding last-year pupils, but including the Polish IOI team). Training of the IOI team includes also two regional international contests: the BOI and the Central European Olympiad in Informatics (CEOI).

Qualification of the POI contestants for all the international contests (IOI, BOI and CEOI) is based on the results of the final stage of the POI. When choosing the BOI team, two goals are combined: training of the IOI team and training of promising future top contestants. Therefore, the Polish BOI team consists of top six contestants, excluding the last-year pupils. The BOI results are not used to qualify to the IOI team. Hence, the atmosphere during the contest is less stressful and more friendly and joyful. It seems that the BOI is the most amicable and least formal among all the international competitions in which Poland participates.

3.8. *Sweden*

Sweden has nine years of compulsory school, followed by three years of secondary school (gymnasium). In the compulsory school, informatics is integrated in other subjects, but in secondary school it is taught as a separate subject (30 minutes/week; not mandatory but always offered), with the focus being on using typical office software and the Internet. Many secondary schools offer programming as an optional subject. These courses exist on three levels (up to 2 hours/week) and typically include the fundamentals of a programming language, basic algorithms and special directions such as web programming.

The national programming olympiad has been organised since 1990, with the number of participants increasing to around 300 in the end of the 90s but decreasing to around 120 in the mid-00s. Also the top layer was significantly narrowed, probably reflecting the end of the generation growing up with computers that one had to program to do anything interesting. In the last years, the number of participants has increased again to around 200.

The qualification round is organised at those secondary schools that have interested teachers (currently around 60 schools). During the last three years, students from other schools have had the possibility to qualify through an online contest with a separate set of tasks. However, a major problem is to reach interested students that are not enrolled in programming courses at school. The national final with 30–40 participants is also held at the schools. The tasks are significantly easier than at the international level, and only one or two usually require knowledge of non-trivial algorithms. Although the dominating languages are C++ and Java, any language is allowed and there have been finalists writing in, e.g., Visual Basic, Python, Perl, Ruby and Haskell.

Sweden has never organised any training camp, and therefore the BOI serves an important purpose: it is usually the first time the students meet other persons with similar capabilities, and it is also the spark that ignites their interest for algorithms and motivates them to practice for the IOI. Nevertheless, the team for the IOI is selected already at the national competition; the two extra students in the BOI are selected among the finalists that are not at their last year.

4. Organisation of a BOI Contest

4.1. *Contest Organisation, Schedule and Other Activities*

The typical schedule of the BOI is a bit compressed compared to the IOI. The arrival of teams, opening ceremony and practice session are all scheduled to the first day. Thanks to the regional nature of the event, the travel distances are relatively short and most teams manage to arrive within the planned half-day slot. The combined arrival and opening day is immediately followed by two competition days with some leisure activities (sports, picnic, zoo, etc.) scheduled to fit between the competition rounds and jury meetings. The fourth day is a relaxing one (for the guests, at least) with an excursion, closing ceremony and a party. The last day is scheduled for departure.

Hosts may choose to extend the BOI with an additional excursion day. On the other hand, sometimes even the half-day excursion is skipped and then the awarding and closing ceremony is scheduled already before lunchtime. This way the teams can catch an overnight trip. Having a party in the evening of the closing day is more common, though.

BOI does not have any official regulations or syllabus for the tasks: all related regulations are agreed together with the leaders. In the IOI, a discussion to get an official syllabus has been started (Verhoeff *et al.*, 2006).

Grading systems are mainly developed and maintained by the host country, although there have been some exceptions. During BOI 2000 in Sweden, Polish grading system was used, and in BOI 2005 in Finland, Germany's grading system was used. Also, Lithuania has used Korea's (host of IOI 2002) grading system.

4.2. *Task Selection Process*

Task selection process used in the BOI is quite informal when compared to more formal selection process used in the IOI (Burton and Hiron, 2008; Diks *et al.*, 2008). Tasks are discussed in advance using e-mail. Typically, the call for tasks is sent out in February. About one month is given to prepare the task proposals. It is expected that each country comes up with one proposal; however, it happens that not every country prepares its proposal, while the organising country sometimes has several proposals. This is natural as the organisers usually have a strong scientific team to manage the contest and to work on the tasks. The proposals come in draft version (i.e., the wording may need improvement, constraints need to be fixed) together with some kind of solution suggestion.

The tasks are discussed on-line for two or three weeks. Team leaders ask and discuss various task related questions, point out if they had similar tasks in their national contests or training. In case of similar tasks the discussion goes on to what degree the tasks and solution are similar, can the task still be used in the contest or may be just as warm-up task. Moreover, the assignment of tasks to the two competition days needs to be determined. Typically, team leaders take into account the following principles: (1) the second day should be slightly harder than the first day, and solutions might be slightly longer; (2) similar tasks should not appear on the same day. After some discussion, votes are cast and the task sets are chosen. Then the host scientific committee works on the final versions.

The situation is different with test data. Some organisers prefer to prepare the tests by themselves; some expect the task authors to work on the tests. After task descriptions are finalised, the team leaders translate them in advance before BOI. Just as in the IOI, there are six tasks to solve during two competition days in the BOI. The tasks in the BOI also resemble the tasks in the IOI, although tasks other than traditional input-output tasks have rarely been seen in the BOI.

During BOI the team leaders discuss the tasks once again before presenting final versions of translations. Often the discussions are very short and last less than half an hour. Sometimes ambiguities are discovered, the wording needs to be changed and it takes longer till the final English versions and final translations are prepared.

4.3. *Task Analysis of BOI Contests*

We have analysed all the BOI tasks in the years 1995–2008 and classified them into five categories:

- Combinatorial search tasks where it is possible to go through all reasonable solutions (possibly with some optimisations) and choose the optimal solution.
- Dynamic programming tasks where the problem can be divided into independent sub-problems.
- Graph theory tasks where the problem can be transformed into a graph and solved by a graph algorithm.
- Mathematical tasks which include the tasks concerning arithmetic, geometry, number theory and probability.
- Ad hoc (creative, inventive) tasks which require an original nontraditional solution method or algorithm, and cannot be classified into the above categories.

Of course, it is not always clear which of these categories is the most suitable for a given task. For instance, some tasks can be seen both as combinatorial search tasks and as graph theory tasks. Similarly, almost all tasks include some ad hoc elements. However, this classification, though unavoidably incomplete, sheds some light on the distribution of the problem types in the history of the BOI.

Table 2 shows the number of tasks in different categories in the years 1995–2008. We have divided the years into three groups (1995–1999, 2000–2004 and 2005–2008) to examine long-range changes in the problem types.

In the years 1995–1999, many tasks falling into combinatorial search and ad hoc categories demanded careful implementation of straightforward algorithms. For example, one had to simulate an algorithm given in the task definition, evaluate an arithmetic expression or sort a table according to specific criteria.

In the years 2000–2008, graph theory and dynamic programming tasks dominated and most of the tasks required special knowledge of algorithms. This is an important change in the history of the BOI: in the first years, one could achieve full points from some tasks with basic programming skills, which is nowadays seldom the case.

Table 2

Task classification of the BOI tasks 1995–2008

	1995–1999	2000–2004	2005–2008	Total
Combinatorial search	9	3	2	14
Dynamic programming	3	6	9	18
Graph theory	5	9	5	19
Mathematics	3	5	2	10
Ad hoc	10	7	6	23

4.4. *Competition Results at BOIs and of BOI Countries*

Over the years, the BOI competition has developed. The very first Baltic Olympiads had the goal to help the teams of the three Baltic countries to prepare for the IOI as well as to aid in selecting IOI teams. Therefore the organisers of the first BOIs wanted to keep the high value of the medals and the medals were awarded based on the contestants' scores, not taking into account the number of the participants. The contestants strived to beat at least two members of their team (which would be a ticket to IOI) rather than get a medal. Since the BOI 2000, the IOI conventions for distributing medals (half of the contestants are awarded) were adopted. Since BOI 2001 in Poland, also the maximum score (100 per task, 600 overall) is in accordance with IOI. In all BOI contests, there have been six tasks (three tasks in both days). In the competitions from 1995 to 1999, the maximum score was 200. Maximum score per day was 100, and the maximum score for a single task varied between 20 and 50 according to team leaders' estimations on how hard it is to solve the task. In the BOI 2000, the maximum score was 300.

Table 3 lists the BOI competitions from 1995 to 2008, giving the number of participating countries and contestants, and showing how many and at what score boundaries medals were awarded. When considering contests starting from 2001, the gold medal limit has varied between 315 and 495, and the bronze medal limit has varied between 132 and 255.

As complementary information, Table 4 shows the performance of the BOI countries at the BOIs and, in comparison, at the IOIs. The most successful BOI countries so far have been Poland with 20, Lithuania with 6 and Estonia and Finland with 4 gold medals. Notice also that the USA team got two silver medals in 1999 and the Israel team got one

Table 3
The BOI contests 1995–2008

Year	Location	Countries	Contestants	Medals (G/S/B)	Medal Boundaries (G/S/B)
2008	Gdynia, Poland	10	59	4/9/13	364/205/134
2007	Güstrow, Germany	9	55	4/10/14	315/228/134
2006	Heinola, Finland	9	53	4/8/14	440/365/255
2005	Pasvalys, Lithuania	8	46	4/7/12	495/400/215
2004	Ventspils, Latvia	8	48	5/8/11	362/267/132
2003	Tartu, Estonia	7	48	5/9/15	435/247/145
2002	Vilnius, Lithuania	8	52	4/8/14	400/241/140
2001	Sopot, Poland	8	49	4/8/12	420/250/190
2000	Haninge, Sweden	7	38	2/6/8	264/222/132
1999	Riga, Latvia	7	44	1/3/4	199/157/144
1998	Tartu, Estonia	5	40	2/2/5	152/129/101
1997	Vilnius, Lithuania	4	36	1/2/3	152/127/104
1996	Riga, Latvia	3	20	1/1/1	171/144/114
1995	Tartu, Estonia	3	28	1/3/8	184/154/119

Table 4
Statistics on the BOI countries and medal distributions

Country	Joined BOI	Joined IOI	Students in 1st national round 2008	BOI medals (G/S/B)	IOI medals (G/S/B)
Denmark	2000	1992	Unknown	0/0/5	3/5/13
Estonia	1995	1992	53	4/6/21	5/15/21
Finland	1998	1992	33	4/8/17	5/17/21
Germany	2001	1989	1106	3/13/10	10/22/26
Latvia	1995	1992	200	2/13/26	4/16/28
Lithuania	1995	1992	3307	6/10/21	2/18/29
Norway	2003	2001[3]	0	0/1/1	0/1/3
Poland	1997	1989	949	20/24/13	26/22/21
Sweden	1998	1990	160	2/4/13	11/17/17

[3] Norway also attended in 1990 on a private initiative by a professor.

silver and one bronze medal in 2005. When considering IOI competitions, Poland has received 26, Germany 10 and Estonia and Finland 5 gold medals.

5. Analysis of Tasks and the Solutions of BOI 2007

In order to recognise what kind of basic algorithms and problem solving techniques are required in BOI contests, we analysed tasks and solution submissions of BOI 2007.

5.1. *Tasks*

In the BOI 2007 the following tasks (Battré, 2007) were used: Escape, Sorting and Sound on Day1, and Fence, Points and Sequence on Day 2. The maximum score for one task was 100.

In the task Escape, a group of prisoners is trying to escape from a prison. The only way out goes through a canyon. In the canyon there are soldiers standing on fixed positions. The range of view of soldiers is also fixed. The contestant should write a program that determines whether prisoners can pass the canyon unnoticed. If this is not possible, then the contestant should determine the minimum number of soldiers that have to be eliminated to pass the canyon safely. Partial scores can be achieved with a standard tree traversal algorithm (depth-first-search or breadth-first-search) and to get full points, the contestant should apply a maximum flow algorithm to find a minimum cut of the corresponding graph.

Task Sorting required the contestant to sort a list of players and their scores in decreasing order, using only an operation which moves a player from position i to position j without changing the relative order of the other players. The cost of such an operation is $i+j$. The contestant should find a sequence of sorting moves that minimise the total cost.

The optimal solution requires a dynamic programming algorithm; partial scores can be achieved with a brute force algorithm.

In Sound the contestant should analyse a number sequence representing air pressure to find the maximum length of a subsequence where the difference between the lowest and the highest value is less than or equal to a given parameter. Algorithms based on scanning the sequence more than once will give only partial points; the optimal solution requires scanning the input sequence only once and maintaining suffixes and prefixes of some subsequences. The method can be classified as a dynamic programming approach since the contestant should store values of certain partial solutions and use them to get an overall solution.

The name of the fourth task was Fence. The input is a list of rectangular areas (buildings of an estate) on a plane. One of the buildings is the main mansion of the estate. The goal of the task is to design an algorithm that finds minimum length of a fence for the main mansion such that the fence does not overlap any other rectangles. The problem can be modelled as a graph and can be solved using Dijkstra's algorithm for shortest paths.

The fifth task, Points, was a combinatorial problem where the contestant should find out how many possible ways there are to connect the given $3 * N$ points on a grid to form a polygon. The number of possible configurations should be counted modulo 1,000,000,000. To solve the problem the contestant should invent a correct recurrence equation.

In the last task, Sequence, input is a number sequence which should be manipulated using only the operation *reduce* (i) which replaces two consecutive elements i and $i + 1$ of the sequence with a single element which is maximum of these two elements. The cost of the operation is the maximum of these elements. The goal is to reduce the length of the sequence to 1 with the minimal total cost. Basic dynamic programming and greedy algorithms yield only partial score; to get full score, a greedy algorithm with an auxiliary stack implementation is needed.

5.2. *Solutions*

55 contestants participated in the BOI 2007. 39 of them used C++, 10 used C and 5 used Pascal in their solutions. One contestant used both C and C++. On the first day 464 and on the second day 335 submissions to the grading system were counted.

Table 5 lists, for each task, its type and solution method, statistical data on the number of submissions, scoring and length of the solutions. Second row lists the number of contestants who submitted a solution for the task. Task Sorting got solutions from only 28 contestants and the other tasks received 35–51 solutions, so Sorting can be seen as the hardest task of the contest. Tasks Sound and Sequence got 51 solutions each. The average score for Sorting was only 4.73 points, and for tasks Sound and Sequence contestants got on average 51.8 and 50.91 points, respectively. Average total score was 153.47 (bronze medal limit was 134).

The fourth row of Table 5 contains the average number of submissions for each task of those contestants who submitted at least one solution for the task. In the parenthesis is

Table 5
Solution statistics of the BOI 07 contest

Task	Escape	Sorting	Sound	Fence	Points	Sequence
Task and solution keywords	Graph, dfs-search maximum flow	Number sequence, dynamic programming	Number sequence, dynamic programming	Graph, shortest paths	Mathematical, combinatorics	Mathematical, dynamic programming, greedy
Solutions	44	28	51	40	35	51
Ave. score	22.58	4.73	51.8	4.09	19.36	50.91
Ave. submission	2.05(6)	1.09(5)	2.35(7)	1.87(9)	1.62(7)	2.36(15)
Ave. lines	138.75	99.5	75.29	150.78	195.37	60.86
Ave. words	346.7	267.39	208.59	478.05	1460.31	149.61

the maximal number of submissions from one contestant for the task. We noted that seven submissions were done for the wrong task, and six times a correct file was submitted after the wrong submission, but in one case the last submission remained incorrect.

Rows five and six contain average number of code lines and average number of words (counted using Unix *wc*-command). We took into account only the last submitted file. Contestants scored on average most points from tasks Sound and Sequence and also the length of the solutions for these two tasks were the shortest, on average 75.29 and 60.86 lines and 267.39 and 149.61 words, respectively. Longest solutions were submitted for the task Points (average length 195.37 lines and 1460 words), although there was one extreme case included: one contestant submitted a solution with 1074 lines and 32217 words and the other solutions were roughly ten times shorter. The contestant tried to enumerate in code a high number of distinct solution cases for this task.

There were also very short solutions for some tasks. If the length of the solution was less than ten lines, we noted that the algorithm usually gave only constant solutions (0 or -1) to all test cases.

6. Discussion

This article provides insights into the history of the BOI and into the inner workings of its competition. Although the event aims to be similar to the IOI, it is different in many important aspects. The main difference, probably, is the co-operative task development and selection process. This process ensures that the leaders of all participating delegations are well acquainted with the tasks, so that they will be able to precisely understand the results their contestants achieve in the competition. Thus, the BOI results provide a sound foundation for selecting the IOI teams as well as for improving or adapting further training activities.

It is subject to discussion whether the IOI task development and selection process could be influenced by the BOI spirit. Success at the IOI is very important to many delegations, so that it is necessary to keep tasks secret. Keeping tasks secret to contestants but opening them to team leaders would require a completely different organisation scheme for the IOI – similar to that used for the IMO (International Mathematical Olympiad). For a smaller number of countries whose delegation leaders trust each other not to communicate tasks to contestants in advance, the BOI model proves to be very successful in organising a shared-load competition every year and integrating countries with different levels of experience in contest organisation.

Our positive experiences in organising regional contests encourage us to recommend similar practices for other countries in the IOI community.

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T. Poranen is a university lecturer working at the University of Tampere, Department of Computer Sciences. He received his PhD degree in 2004 and since then he has been teaching software project related courses. His research interests vary from topological graph theory to software development. He was a deputy team leader of Finland's BOI 2007, IOI 2007 and IOI 2008 delegations.

V. Dagienė is professor working at the Institute of Mathematics and Informatics and Vilnius University. She has published over 100 scientific papers and many methodical works, written more than 60 textbooks in informatics and IT for secondary education. She has been chair of Lithuanian Olympiads in Informatics for many years, established the International Contests on Informatics and Computer Fluency "Beaver". She is vice-chair of the Technical Committee of IFIP for Education (TC3), member of the European Logo Scientific Committee, an elected member of the IOI International Committee (2006-2009). She is the Editor-in-Chief of the international journal "Informatics in Education".

Å. Eldhuset is about to complete his master's degree in computer science at the Norwegian University of Science and Technology, where he also is employed as a teaching assistant. He gives lectures in algorithms, programming and discrete mathematics. He won a bronze medal in IOI 2003 and joined the Norwegian Olympiad in Informatics as a co-organiser upon entering the university; he was deputy team leader and team leader for Norway's IOI delegations in 2005 and 2006, respectively.

H. Hyyrö received PhD in computer science in 2003 and is currently an assistant professor at the Department of Computer Sciences, University of Tampere, Finland. He has been responsible for organizing the algorithmic (i.e., programming) part of the Finnish national informatics competition for high-school students in the years 2007 - 2009. During this time he has also been the leader of Finland's IOI delegations.

M. Kubica, PhD in computer science, assistant professor at Institute of Informatics, Faculty of Mathematics, Informatics and Mechanics, Warsaw University, scientific secretary of Polish Olympiad in Informatics, IOI-ISC member and former chairman of Scientific Committees of BOI 2008 in Gdynia, IOI 2005 in Nowy Sacz, CEOI 2004 in Rzeszow and BOI 2001 in Sopot, Poland. His research interests focus on combinatorial and text algorithms.

A. Laaksonen studies computer science at the University of Helsinki. He has been a contestant in BOI and IOI several times: now he takes part in training Finnish teams for these competitions.

M. Opmanis is researcher at the Institute of Mathematics and Computer Science of University of Latvia. He is deputy team leader of Latvian IOI team since 1996 and was team leader of Latvian team at Baltic olympiads in informatics since 1995 till 2007 and on 2009. M.Opmanis was head of jury of Baltic Olympiad in Informatics at BOI 1996, 1999 and 2004.

W. Pohl was educated in Computer Science, and received a PhD in 1997 from the University of Essen, Germany. For many years, he investigated the use of artificial intelligence techniques for the improvement of interaction between humans and machines. In 1999, he changed position and perspective by becoming executive director of the German Federal Contest in Computer Science. Among his responsibilities is to coach the German IOI team and lead the German IOI delegation. Now, his interest lies in improving computer science contests, establishing new ones, and work on diverse other projects, everything in order to popularise computer science among youth. Hence, he coordinates the German participation in the international contest "Bebras". From 2003 to 2006, he was elected member of the IOI International Committee, and briefly held the position of executive director of IOI in 2006.

J. Skūpienė is a younger research fellow in the Informatics Methodology Department in the Institute of Mathematics and Informatics. She has published about 10 scientific papers. She is a member of the Scientific Committee of National Olympiads in Informatics since 1994 and a team leader in IOI since 1996. For a few years she was director of studies of Young Programmers' School, since 2004 she has been a coordinator of informatics section in the National Academy of Students. She is author/co-author of four books on algorithms and algorithmic problems.

P. Söderhjelm holds a PhD in theoretical chemistry concerning how to calculate accurate interaction energies in biological systems. He has a strong interest in problem solving, algorithms, and school issues, and has been involved in the Swedish national programming olympiad since 1999 after having participated twice in IOI. He was the coordinator of BOI 2009.

A. Truu is a software architect with GuardTime AS. He has been involved in programming competitions since 1988, first as a contestant and later as a member of the jury of the Estonian Olympiad in Informatics as well as a team leader to the Baltic, Central European and International olympiads and the coach of Tartu University's team to the ACM ICPC.