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Expecting the Unexpected

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Abstract. In recent IOIs, the IOI community has observed creative tasks such as *'Language'*/*'Maze'*/*'Saveit'* (IOI Tasks, 2010), *'Parrots'* (IOI Tasks, 2011), and *'Odometer'*/*'Supper'* (IOI Tasks, 2012) that caught many contestants and their coaches off-guard. This is because it is very hard to train our students to be 100% ready for such *unexpected* tasks. Reading the IOI 2013 call for tasks requirements (IOI Call for Tasks, 2013) points us towards more of IOI tasks of such nature. In this paper, we share how the Singapore IOI team expects the unexpected.

Key words: IOI, creative task.

1. Introduction (IOI 2010)

The author is a regular member of the IOI community having attended the past three IOIs (2010 @ Waterloo, Canada; 2011 @ Pattaya, Thailand; and 2012 @ Sirmione–Montichiari, Italy). In the past three years, the IOI community has observed creative tasks that challenge the best high school students in informatics. In this paper, I seek to highlight some tasks which surprise both the students and the coaches *more* than the other – more traditional – tasks. In this paper, we define a *traditional task* as a task that asks students to write a program that reads input, performs some computation within the stipulated time and memory constraints, returns output, and is graded mainly based on the correctness of students' output against the judges' output.

On the night before IOI 2010 Day 1, the delegation leaders were presented with the task '*Language*' (task author: Gordon V. Cormack) – a problem on the field of *Information Retrieval* that has only been used once many years ago in IOI 1991 (IOI Tasks, 1991). In this task, students are given a sequence of Wikipedia excerpts, and asked to guess the language of each, in turn. After each guess, the students' program is given the correct answer, so that it may *learn* to make better guesses the longer it plays. The students' program is graded based on 'accuracy' – a performance metric that was *never*[1]. *used before* in IOI (Cormack, 2010). Upon seeing such task, many delegation leaders voiced their opinions on such task. Many lauded the novelty of the task but there were some who had reservations that some students would not be able to do well (or might skip the task altogether) as the task fell outside the IOI syllabus (Forišek, 2009). That night,

[1]This statement is based on IOI 2008–2012 tasks. The author has limited experience of the older IOI tasks.

this task was eventually voted to be used in the IOI 2010 Day 1 by the General Assembly (IOI GA Minutes, 2010). It turned out to be successful with most students attempted it. Using 'accuracy' as the performance metric yielded a good, smooth score distribution that showed which students were more creative that day.

Things became more 'exciting' when the IOI 2010 Day 2 problem set was presented to the delegation leaders as it contained task *'Maze'* (task author: Michal Forišek) and *'Saveit'* (task author: Mihai Pătraşcu). The task *'Maze'* is a variant of the '*longest path*' problem which is known to be NP-hard (Garey and Johnson, 1979) and thus has no polynomial solution. However, the test cases were fixed and made available to the students, making this a more approachable output-only task. Students were graded based on the *longest paths* that they can generate for each of the test cases. Students were free to use any computing tools that they have in their workstation to generate these longest paths. The task *'Saveit'* is a '*data compression*' task which illuminated the delegation leaders and the students as to why the organizers insisted on using the new judging system (RunC, 2010–2011) at that time. The novel part of task *'Saveit'* is this: students have to program *two* independent procedures that are inverses to each other: an encoder and a decoder. The communication format is not prescribed. The decoder *programmed by the student* must be able to decode the data from the encoder that is also *programmed by the student*. The grader runs these two procedures and gives higher scores to programs that use a fewer number of bits (which means better communication efficiency).

Based on the success of task *'Language'* on Day 1, there was no major objection for these two creative tasks (IOI GA Minutes, 2010). These two creative tasks obtained mixed results. The result of *'Saveit'* was okay, but too many students stuck at 50 points and only a few scored 25, 75, or 100 points. The result of *'Maze'* is again a smooth score distribution, which implies that scoring a few points in this task very important especially for students around medal boundaries that year.

IOI 2010 was closed on a high note: this scientific experiment was successful. With three unexpected tasks like that, the medalists were worthy winners. For the delegation leaders (and coaches), we all went home with a big homework: IOI training would never be the same again.

2. What We Did in 2011 (Preparation for IOI 2011)

For IOI 2011 preparation, I decided to train the Singapore students on *several* classic NP-hard problems (Garey and Johnson, 1979) that I had studied during my PhD days. We discussed on how to optimize the classic O($n^2 2^n$) DP solution for Traveling Salesman Problem (TSP) so that it can be used to deal with instances up to $n = 19$ or $n = 20$ (previously such a DP solution is already too slow for $n = 16$ or $n = 17$). We also discussed how to solve the smaller instances of the Quadratic Assignment Problem (QAP) (Halim *et al.*, 2007) and the Low Autocorrelation Binary Sequence (LABS) problem (Halim *et al*., 2008) using only techniques that are allowed in the IOI syllabus (Forišek, 2009).

Obviously it is very hard (and near impossible) for the high school students to reach the author's 3–4 years of PhD work in just 5 contest hours and mainly only using the techniques in the IOI syllabus that have been exposed to them. Nevertheless, it was a fun and eye opening training. I found that some students (the eventual medalists in IOI 2011) managed to score highly, getting respectable solution quality for these NP-hard problems compared to the best results found by the author (using various local search techniques that are definitely *outside* the IOI syllabus).

The source of NP-hard problems for task inspiration may be plentiful (e.g., Garey and Johnson, 1979). However, setting up such training tasks is *very painful* as the trainer must properly define a *restricted subset* of the original NP-hard problem so that the training task becomes approachable for high school students. Otherwise, too many students will end up with near 0 score and thus become discouraged. We need to scale down the task so that a few students (the ones that have the potential to be selected in the team that year) will be able to get reasonably good solutions in 5 contest hours.

During the actual IOI 2011, the same judging system (RunC, 2010–2011) was still used. Therefore, some established countries in the field of informatics who had done their homework would have expected something unexpected.

I was betting on another NP-hard task in IOI 2011, but there was none. There was no major surprise on Day 1 and there were 'too many' potential gold medalists scoring 300 points that day – that is, full marks for all three tasks.

However, on IOI 2011 Day 2, another creative task *'Parrots'* (task author: Jittat Fakcharoenphol) was used. It is about '*Computer Networks*'. It has similar flavor to *'Saveit'* in the sense that it leverages upon the strength of RunC judging system. It uses the concepts of bit manipulation heavily (which I am grateful because I covered this in Singapore training program). Learning from the score distribution of *'Saveit'* in 2010, the Scientific Committee made another breakthrough by setting an 'interesting' scoring system for each subtask (not just 5 fixed scores: 0, 25, 50, 75, 100 as in *'Saveit'* but 4 fixed scores 17, 17, 18, 29, and *variable* scores up to 19 points for the last/hardest subtask in *'Parrots'* to differentiate the top students). The tasks selected in Day 2 and the scoring system managed to differentiate the top students. Only one student and the eventual winner managed to get the full 600 points over two contest days. This highlights the needs of such creative tasks to challenge today's best IOI students.

3. What We Did in 2012 (Preparation for IOI 2012)

After seeing two instances of 'data compression' tasks in *'Saveit'* (IOI Tasks, 2010) and *'Parrots'* (IOI Tasks, 2011), I decided that the Singapore team should do something about such a task type in our training program. Therefore, we upgraded our local grading server (Mu Judge, 2009–2013) to handle such a task type and I set a task titled *'Compress'* as one of the tasks for the Singapore IOI selection test 2012. It is about the field of '*Information Theory*' where students are asked to write a 'zip' program to compress the given set of text files *as small as possible* and then write another 'unzip' program to decompress their

own compressed text file to get the original file *without any information loss*. In this task, the text files to be compressed are given so that the students can utilize whatever properties that they see in the given test files and use those properties for their benefit.

With this single task, I wanted to know which students are more comfortable in dealing with the code/decode tasks akin to *'Saveit'* and *'Parrot'* and which students know (or manage to 'reinvent') various data compression techniques during the 5-hours contest time, i.e., using Run Length Encoding, using the more efficient larger base to store integers, using the more space efficient adjacency list to store a graph data structure compared to adjacency matrix, using Huffman encoding (optional, as this is outside the IOI syllabus), and various other small tricks to further compress the given test files especially after looking at the properties of the text files.

In IOI 2012, my bet on this training type was correct. In the actual IOI 2012 Day 2, task *'Supper'* (task author: Richard Královič) was selected as one of the tasks. This task uses data compression as *part of* the overall solution and uses the same interface style as with *'Saveit'* and *'Parrots'* although the judging software was new: CMS (Maggiolo and Mascellani, 2012). It is therefore not surprising (and somewhat expected) that the Singapore IOI team managed to get reasonably high scores in that task[2] (see Table 1 – the data is not shown in detailed fashion to keep the spirit of IOI as an individual contest and not a country-based contest).

IOI 2012 Day 1 also had its surprises. The task *'Odometer'* (task authors: Michal Forišek, Giovanni Paolini, and Matteo Boscariol) redefined the meaning of *output only* task. In this task, the students do not submit the output of a certain input file after processing them locally, but the students submit 'codes' written using a meta-language to be graded by a special judging mechanism[3]. Each subtask is like a standalone problem on its own. This task can be a (very) *time consuming* task as students need to first understand the meta-language via some experiments before they can actually solve the subtasks. Good time management was compulsory in order to do well in all the 3 tasks given that day. There were 5 subtasks for *'Odometer'* but I can foresee that the Scientific Committee can easily increase the number of such subtasks to 6 or 7 to further increase the challenge of this task if they foresee the need to do so (it happened to be enough to differentiate the eventual winner and the runner up of IOI 2012). Tasks of this nature are frequently used in the Internet Problem Solving Contest (IPSC, 1999–2013). Fortunately I asked Singapore team members to join such a contest every year.

In terms of results, no country got 400 marks for these two creative tasks and task *'City'* (i.e., all 4 students from that country scored full 100 marks) whereas there exists at least one country with 400 marks for the other 3 tasks of IOI 2012 (i.e., task *'Rings'*, *'Scrivener'*, and *'Tournament'*). I foresee that with this trend of increasing skill level of the top students, the Scientific Committee of the future IOIs have no choice but to keep surprising these brilliant students (and their coaches) by using more and more creative tasks.

[2] Another potential reason is the *length* of the task description of *'Supper'*. Many students from non English-speaking countries have difficulties understanding the requirements of the task while this is not a problem for Singapore students. However, I believe future IOI task descriptions will be shorter than this task.

[3] CMS (Maggiolo and Mascellani, 2012) had to be tweaked to support this task.

Singapore's country rank on three recent creative tasks (by summing 4 students' scores). Data obtained from SnarkNews (2006–2013)

Task	Parrots (2011)	Odometer (2012)	Supper (2012)
Singapore's rough rank	Top 40 percentile out of 78 countries	Top 10 percentile out of 82 countries	Top 10 percentile out of 82 countries

4. Closing Remarks

I am thankful to the International and Host Scientific Committee as well as the various task contributors for their creative tasks. Though the more creative they are, the more difficult the IOI training will be, I feel that it should be the case as the IOI is the pinnacle of informatics competition among high school students.

The tasks selected by the Scientific Committee indirectly determine what will be included in the training program of various countries – especially the more established ones – in the following year. Although it is rather impossible to correctly predict what kind of tasks will appear in the future IOIs – as illustrated in Singapore case in 2011, we know that future tasks will be more to the creative side than the classic side, as shown in the recent IOI Call for Tasks (IOI Call for Tasks, 2013).

I believe that we have to train our students to be creative problem solvers by purposely exposing them to various non-classical tasks from diverse fields of Computer Science curriculum and then purposely use some of those tasks as part of the selection criteria. This way, the creative students are preferred over those who mastered many algorithms but not creative problem solvers. We hope that the selected creative students can perform as well as possible on these unexpected tasks during the actual IOI.

In Singapore, we do not have that many training tasks of this nature yet. The most obvious reason is due to the difficulty in preparing such creative tasks in the first place. During the actual IOI conference 2013, I am planning to release *some* of our 'creative' tasks to the delegation leaders to be used in the training programs in their countries.

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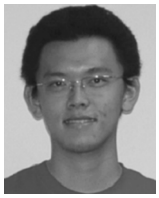

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