The 2005 Australian Informatics Competition

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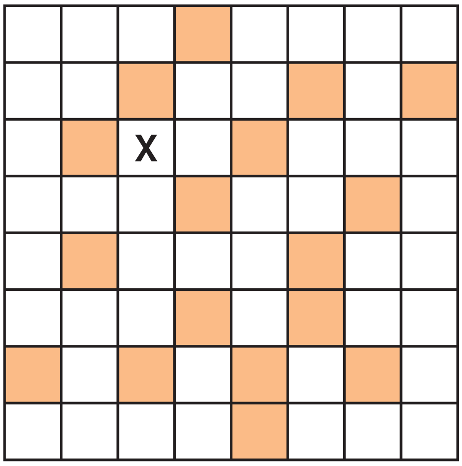
The Australian Informatics Competition is a non-programming competition aimed at identifying students with potential in programming and algorithmic design. It is the first step in identifying students to represent Australia at the International Olympiad in Informatics.

Introduction

Try these problems!

Dungeon

A token (marked X in the diagram) is in a maze. You may move the token around according to the following rule: in each move the token can be moved any distance either horizontally or vertically, but can not pass over or stop on a shaded square.



For example, from its starting position the token could travel either one square right, one square down, two squares down or three squares down. What is the minimum number of moves required to ensure that the token can reach any white square from its starting position?

Game

You are playing a rather unusual game on a 4 × 4 grid in which each square contains a number. You begin at the top left square of this grid and you must travel to the bottom right square. You must move one square right or one square down in each move.

To begin with you have a score of 0. Each time you move to a new square, you halve your current score (rounded down if necessary), and add the value of this new square. Your aim is to reach the bottom right square with the lowest score possible. For example, consider the following grid:

0	3	9	6
1	4	4	5
8	2	5	4
1	8	5	9

The smallest possible final score is 12 which can be achieved as follows:

Move	***Square***	***Score***
begin		0
down	1	1
right	4	4
down	2	4
right	5	7
right	4	7
down	9	12

What is the smallest possible score for the following grids?

0	4	14	6
6	10	2	10
5	8	12	7
14	12	16	17

0	2	1	1
10	11	13	7
5	7	10	8
5	5	5	10

0	20	12	1
18	9	11	6
11	9	9	14
2	14	9	9

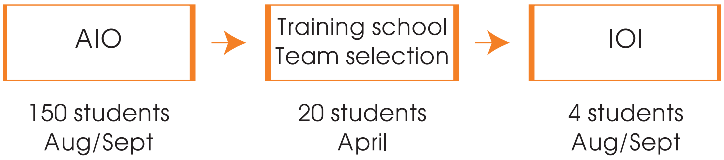
These problems were taken from the 2005 Australian Informatics Competition (AIC). The AIC is the first step in identifying students who will represent Australia at the International Olympiad in Informatics (IOI). The IOI is one of a number of olympiads held annually in differing countries. (Other olympiads are held in Mathematics, Biology, Physics and Chemistry.) The IOI is the newest of the olympiads, the first being held in 1989. Australia has participated every year since 1999. About 80 countries participate in the IOI, with four students representing each country.

The road to the International Olympiad in Informatics

The IOI is a programming competition, with a heavy emphasis on algorithmic design. Informatics is not taught at most schools, and the level of algorithmic design required by the IOI is not taught at all. Students with potential are typically self-taught programmers, with no knowledge of algorithm design, and often are not outstanding academically. They must be taught this discipline.

Until 2005, potential students were identified by an Australia wide programming competition, now called the Australian Informatics Olympiad (AIO). Based on their performance in this competition, 20 students were invited to attend a training school. At the end of the training school, selection exams were held and the team chosen to attend the next IOI. In the selection exams, as in the AIO and the IOI, students write computer programs that are automatically marked by running the programs against a set of pre-determined data.

The pattern of activities until 2005 was



This timeline was less than ideal. Combining team selection with the training school meant that there was no time for students to absorb the material before the selection exam. Another source of concern was the small catchment of about 150 students.

In 2005, a number of changes were made. In particular, a pre-programming competition was introduced to identify students with no programming experience, but with talent in algorithmic design. And the training school was moved to December and a smaller selection school held in April. The pattern of activities is now

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The main aim of the AIC is to increase awareness of programming among students and to provide an incentive for them to explore it as a discipline. In particular, it is hoped that students with programming ability will develop it and take part in the AIO.

Problems in the AIC are intended to be interesting and fun. Although students would be expected to spend only 5–10 minutes on a problem in the competition, some questions will be challenging enough to be taken away and discussed afterwards. A feature of the questions is that they are set in a context. They come with a story and a title. This is what happens in the IOI and the AIO. It also helps to make the questions more appealing.

The AIC is run under the auspices of the Australian Mathematics Trust (AMT). Because programming is not taught in many schools, and there is an overlap between mathematical and programming ability, invitations to the AIC are sent to the mathematics teachers at all Australian schools that enter students in the Australian Mathematics Competition for the Westpac Awards (AMC).

2005 was the first year of the non-programming AIC competition. There were two papers: a senior paper for Years 11–12 and an intermediate paper for Years 7–10. Due to the link with the AMT, a decision was made to make the AIC similar in format to the AMC; that is, students answer questions on a mark sense sheet that is marked in the same way as the AMC. This means that the technology and processes of the AMC can be used for the AIC.

The structure of the papers

In the AMC most questions are multiple-choice with five alternatives, while the remainder are questions whose answer is a number in the range 1–999. The AIC papers have 15 questions, the first six being multiple-choice with five alternatives, and the remaining nine requiring a 1–999 answer.

Multiple-choice questions are normally simple "knowledge" questions, such as, "What is the capital of Australia?" In the AIC, as in the AMC, questions are formulated as multiple-choice to allow automated marking. AIC questions cannot be partially solved by eliminating some of the alternatives. Instead, the student is required to solve the problem and then find their answer from among the list of alternatives.

A disadvantage of multiple-choice questions is the effect of guessing. Unless there are penalties for incorrect answers, it is in the students' interests to guess. This introduces a random factor that reduces the effectiveness of the question. Although marking schemes have been devised to reduce the tendency to guess (Clark & Pollard, 1989; Pollard, 1987), generally by giving partial marks for partial knowledge, these are not appropriate for AIC questions.

The 1–999 questions avoid the problem of guessing – in effect there are 999 alternatives. A disadvantage of the 1–999 questions, however, is that because they are automatically marked there is no way of knowing whether an incorrect answer was due to an incorrect algorithm or an error in applying the algorithm to the test data. A further constraint is that the answer must be a number in the range 1–999. This can cause some awkwardness in formulating the answer to the question (see analysis of the responses in "Card Shuffle" below). Even in some cases, good ideas have not been able to be used because they could not be formulated as a question requiring a single number as an answer.

With 1–999 questions, the same problem is used for three sets of data. Using three sets of data for the one problem has a number of advantages. First, it means that students are given more time to solve the problem, as applying their solution to a set of data is quick once it is known. Second, if a student successfully devises the algorithm, their work is not wasted by a single careless mistake. Finally, those setting the competition do not have to dream up as many questions.

Types of questions

There are three types of questions in the AIC. The first, and foremost, is algorithm questions, which aim to test algorithmic ability. That is, to find a set of rules that will solve a given problem. After all, a primary aim of the AIC is to identify students with the ability to devise algorithms. The standard way to test algorithmic ability is to require students to write a computer program which will be tested on unseen data. This is what happens in the AIO and the IOI. However, this is not possible in the AIC. Instead, problems are set that require the student to devise an algorithm and then apply it to some data. "Card Shuffle" (questions 13–15 in the intermediate paper) is one example.

Algorithm questions are generally 1–999, although "Alarm Clock" (question 3 in the intermediate paper) is an example of a simple multiple-choice algorithm question. Algorithm questions are not easy to devise, especially when the level of difficulty has to be carefully matched to students' ability in the context of a one-hour competition.

The second type of question is tracing. In programming, tracing is working out with pen and paper the values of variables after code has been executed. A typical tracing question has the form, "What is the value of the variable *x* after the following code has been executed?" The AIC does not assume knowledge of any programming languages, or even pseudo code, but tracing questions can still be set by asking students to apply rules. "Trainee Spies" (question 3 on the senior paper) is an example.

Although tracing does not test algorithmic ability, it is still an important skill of the programmer — and one learned early. Tracing corresponds to comprehension in Bloom's hierarchy [1], and students learn it early. Most beginning students are comfortable with tracing well before they become competent in programming. Tracing questions are easy to solve, and the first few questions in both papers were tracing questions. One of the aims of the AIC is to give a wide range of students an enjoyable experience, and an easy question or two at the beginning of a paper can go a long way to achieving this, as well as settling students down so that they can perform to the best of their ability in the rest of the paper. Tracing questions are also the easiest questions to construct in the AIC. Almost all are multiple-choice.

Finally there are ad hoc questions. Their solution relies more on logic than the other types of questions, and often several alternatives have to be tried. Although they are not algorithmic *per se*, they do require the systematic fiddling that is the precursor to algorithmic design. They are not easy to devise and there can be a long distance between an idea and a question suitable for the AIC. "Frogs" is an example.

Results

Statistics

The first AIC was held in 2005. The number of students who entered (2300) was very pleasing. As it was a new venture, the papers included questions intended to be on the easy side, especially in the intermediate paper which spanned Years 7–10.

The average [median] number of questions correct for Years 7–10 (intermediate paper) was 5.0, 5.1, 6.6, 8.7 [4, 5, 6, 9] and for Years 11 and 12 (senior paper) 7.5 and 8.1 [8 and 9]. Overall the biggest differences by age were from Years 8–9 and from Years 9–10.

Of the questions included in this paper, "Alarm Clock" was answered correctly by 69% of students, "Dungeon" by 40%, "Spies" by 76%, "Game" by 47% and "Card Shuffle" by 31% of intermediate students and 55% of seniors.

In the 1–999 questions where the algorithm had to be applied to three sets of data, the only question in which the results differed markedly between sets was "Game" where the percentages correct were 48%, 37% and 54%.

Overall, 2.6% of intermediate students and 1.8% of senior students got a perfect score. This was very pleasing, and in line with expectactions.

Analysis of responses for "Card Shuffle" and "Game"

The responses to "Card Shuffle" and "Game" were analysed in some detail. In "Card Shuffle" about 3% of intermediate students put the largest three digits as their answer (986, 986 and 897). This may have been due to misreading the question, or it may have been due to guessing. Another possible way to guess in this problem would be to put in the smallest three digits (431, 321 and 432). Doing so would give one correct answer, question 15. If this happened, there would be a higher proportion of correct answers for question 15 than for questions 13 and 14. Interestingly, there was no evidence of this happening, except for Year 7 students, where the percentage correct for question 15 was about 5% greater than for questions 13 and 14.

"Game" requires some arithmetic. This was a concern when setting the paper, as there is a possibility of arithmetic error. In an effort to minimise this, the size of the grid was reduced (it was originally 5×5) and the numbers chosen so that only even numbers had to be halved. Unlike in the AMC, calculators were allowed.

However there was still evidence of arithmetic errors. A substantial proportion of incorrect answers were within 1 of the correct answer. For the three grids (questions 13, 14 and 15 on the senior paper), these percentages were 10%, 28% and 14% respectively. It is not clear why the second grid had so many errors, especially as 25.5% were one above the correct answer. It is hard to see how to avoid this without rejecting some otherwise good questions. One possibility would be to tell students whether the answer was odd or even, so that students who were one off the correct answer would know that they had made a mistake.

Sample questions

The following questions were taken from the 2005 AIC with the exception of "Frogs" which was considered for the 2006 AIC but rejected as being too difficult.

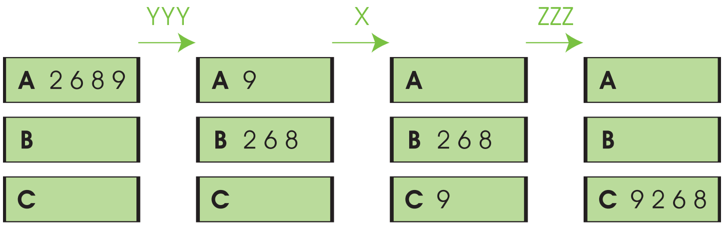
Card shuffle

You have 3 tables, labelled A, B and C. There is a line of cards on table A. Each card has on it a single digit, so that the line of cards makes up a number. Tables B and C begin empty.

You wish to move the cards to table C so that they make as large a number as possible. You are allowed the following moves.

- *Move X*: Take the left-most card from table A and place it at the right-most end of the cards on table C.
- *Move Y*: Take the left-most card from table A and place it at the right-most end of the cards on table B.
- *Move Z*: Take the left-most card from table B and place it at the right-most end of the cards on table C.

For example, suppose that table A begins with the four cards that form the number 2689. The following diagram illustrates the moves YYYXZZZ, giving a final number 9268 on table C.



In each of the following questions, you are given the starting number on table A and you are to work out the largest number that can be formed on table C. You are only allowed to use moves X, Y and/or Z as described above.

In each case your answer should be the final three digits of this largest number. For example, if table A begins with the number 2689 and you believe the largest possible number on table C is 9268 (as illustrated above) you would write "268" as your number.

13. 3 4 9 8 6 1
14. 9 1 2 8 3 4 6
15. 8 6 4 2 9 7 5 3

Trainee spies

The local spy training school is instructing its bright new recruits in the art of disguising messages. They are told to change each letter of the original message according to the following rules

- replace each V in the message with XY
- replace each W in the message with Z
- replace each X in the message with WV
- replace each Y in the message with V
- replace each Z in the message with YW

Because they are spies, they do not use any letters other than V, W, X, Y or Z in their messages.

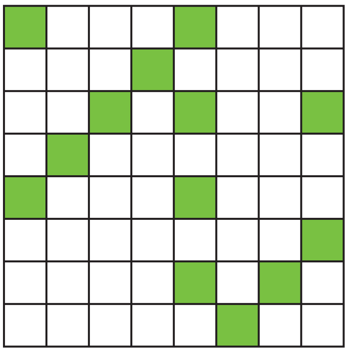
The instructor gives a message to Anne who "disguises" it according to the above rules and passes it on to Bernard. Bernard disguises the message he received and passes it on to Clarice. Clarice in turn disguises the message and passes it to David who disguises it and returns it to the instructor. The final message the instructor gets back is VZZXYXY. What was the original message?

A) V B) W C) X D) Y E) Z

Note that a little analysis will reduce the amount of work in this question, and consequently the chance of making an error.

Frogs

Plants have been planted in an 8×8 grid of plots, one plant per plot. Unfortunately overnight some plants have been jumped on and squashed by frogs. The diagram below shows those plants that have been squashed.



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Frogs only move horizontally, vertically or diagonally. They jump 1, 2 or 3 squares per jump. No frog changes the direction or length of its jump.

The fewest number of frogs possible did the damage to the plants. What is the fewest number of plants that were jumped on by more than one frog?

Comment: This is a nice problem, but difficult to express and also deemed too difficult for the AIC. The answer is given at the end of this paper. Readers are encouraged to try it first.

Alarm clock

You have a clock with four buttons, H+, H–, M+ and M–. These buttons can be used to change the time. The two H buttons change the hours without affecting the minutes, while the two M buttons change the minutes without affecting the hours.

- H+ increases the hours by 1. If H+ was pressed and the hours was 11, the hours would be set to 00.
- H– decreases the hours by 1. If H– was pressed and the hours was 00, the hours would be set to 11.
- M+ increases the minutes by 1. If M+ was pressed and the minutes was 59, the minutes would be set to 00.
- M– decreases the minutes by 1. If M– was pressed and the minutes was 00, the minutes would be set to 59.

The time shows 04:05 and you want to set it to 11:55

What is the fewest number of button presses that you need?

A) 15 B) 17 C) 45 D) 47 E) 750

Conclusion

The AIC was a new venture in 2005. The problems in the competition were constructed to very tight deadlines in their spare time by the author and David Greenaway, a former IOI olympian and now a university student. Few of the IOI countries have a similar non-programming competition, and almost none have the same emphasis on algorithms. One exception is India, although they only have one paper and the problems are more difficult and the paper is much longer. That the AIC questions were set at about the right level of difficulty was a relief, and that over 2000 students entered the AIC was very encouraging. The number of students in other IOI countries' first round competitions varies from about 10,000 to fewer than 20, with a median of about 1,000.

Based on the success of the 2005 AIC it will continue. From 2006 there will be three papers, *junior* for Years 7–8, *intermediate* for Years 9–10 and *senior* for Years 11–12. The problem setting committee has been expanded, although any volunteers for problem setting or moderation would be welcome.

Programming training materials for students and teachers are available from: http://magnet.amt.canberra.edu.au/aio/.

Finally, the answer to “Frogs” is 1. I hope that you had fun solving it.

References

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