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The Australian Informatics Competition

David CLARK[1], Mike CLAPPER[2]

[1] *The University of Canberra, Faculty of Education, Science, Technology and Maths University Drive, Bruce, ACT, Australia, 2617*

[2] *The Australian Mathematics Trust, Haydon Drive, Bruce, ACT, Australia, 2617*

e-mail: David.Clark@canberra.edu.au, Mike.Clapper@amt.edu.au

Abstract. The Australian Informatics Competition (AIC) is the entry-level Informatics competition in Australia. It is a pen-and-paper competition, requiring no programming experience. Most of the questions focus on testing algorithmic ability, with others testing students' ability to analyse algorithms, apply rules and use logic to solve problems. The algorithmic questions include standard algorithms such as breadth first search, dynamic programming and two person games, as well as ad-hoc algorithms specific to a particular scenario. Currently about 7,000 students enter the competition, but there are plans to expand it with on-line entries. The AIC is becoming more relevant with the introduction of algorithmic thinking as a component of the Digital Technologies strand of the Australian Curriculum.

Keywords: informatics competitions, algorithmic thinking, multiple choice questions, problem solving

1 Introduction

The Australian Informatics Competition (AIC) is the entry level Informatics competition in Australia. It is a one hour pen-and-paper competition and does not require or use any knowledge of programming or pseudocode. Students who perform well in the AIC are encouraged to enter the Australian Informatics Olympiad (AIO), an entry-level programming competition. Those who do well in the AIO may be invited to the December Training School and about 40 students will be encouraged to sit the Australian Invitational Informatics Competition (AIIO), and subsequently to enter the French Australian Regional Informatics Olympiad and the Asia-Pacific Informatics Olympiad. Results of these competitions are then used to determine attendance at the final selection school held in April to select the team of four students to represent Australia at the International Olympiad in Informatics (IOI).

The AIC is run by the Australian Mathematics Trust (AMT), which also runs the Australian Mathematics Competition (AMC), and shares some similarities with it, particularly its pen-and-paper format and automatic marking using mark-sense readers. Nevertheless there are some differences. The AMC was set up originally as a widely-accessible competition to enhance mathematical problem solving in Australian schools, and ``higher level'' mathematics such as the Mathematics Challenge and the Mathematics Olympiad were added subsequently. The original aim of the Australian Informatics

Committee was to select an Australian team for the IOI. One consequence of this is that all questions in the AIC have a title and most come with a little story, either real-world or fantasy, as in the IOI. Australia has participated regularly in the IOI since 1999, but the first AIC was not held until 2005. Nevertheless, the aim of Informatics in Australia has expanded to include raising the awareness of algorithmic thinking in Australia and the questions in the AIC are accessible to a wide range of students.

The relevance of the competition will increase significantly with the introduction of Algorithmic thinking into the Digital Technologies component of the Australian Curriculum. Similar curriculum initiatives are occurring overseas and there is increasing demand for resources to help teachers in what for most will be unfamiliar territory. Given the expectation that primary age students will begin to learn algorithmic thinking, the AIC problems committee has committed to introducing an Upper Primary Division of the AIC in 2015.

The AIC was first run in 2005. In that year it attracted a little over 2000 entries. Since then it has grown to over 7000 entries. Most participants are from Australia, with the remainder from New Zealand and Singapore.

In its scope and aims the AIC is similar to the on-line Bebras contest introduced in Lithuania in 2004, although the AIC has somewhat more emphasis in testing algorithmic thinking and does not have Bebras' interactive tasks. An overview of world Informatics Competitions is given by Burton (2010), and a report on the introduction of the AIC was given by Clark (2006). Sample AIC papers are available on the AMT website (`http://www.amt.edu.au/`) where there is also a book "Australian Informatics Competitions Book 1 2005–2010".

2. The Questions

2.1. *Format of the Questions*

The first six questions of each AIC paper are traditional multiple choice questions with five options. This type of question is familiar to students, quick to answer and easy to mark.

The multiple choice questions in the AIC have to be small enough to be understood and solved in just a few minutes whilst still having the flavour of algorithmic thinking. This brevity can, however, leave them to be susceptible to logic and/or educated guesswork.

In order to encourage a more systematic approach to problem solving, three-stage tasks are included. A three-stage task consists of a small problem to solve where there are three sets of data. The first data set is small or simple enough to be susceptible to ad-hoc techniques, but hopefully provides a basis for students to get a feeling for the problem and to develop an algorithm to be used in the remaining data sets. The answers are numbers in the range 0–999. There are three such three-stage tasks.

Each multiple choice question is worth three marks, and each stage of a *three-stage task* is worth two marks, so that the whole paper is marked out of 36.

2.2. *Types of Questions*

Unlike questions in the AMC, which classify into well-defined areas such as algebra, geometry and trigonometry, there are no readily available classifications for AIC questions. Nevertheless, the great majority of questions in the AIC fall into four broad categories: applying rules, logic, analysis, and algorithms. Some questions straddle categories, whilst some pattern matching questions do not fit into any of these categories.

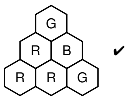
i) *Applying Rules*

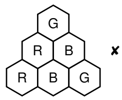
Students are required to apply well-defined rules to a set of data. These questions are always multiple choice, and are typically the first or second question in a paper. They are less frequently used in the Senior paper.

Hrossan Quilts is a typical example. It is an easy question to settle students down and, to quote one of the teachers on the problems committee, "Students like filling in grids".

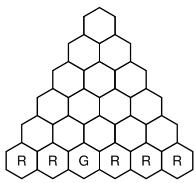
Hrossan Quilts: 2010 Junior Q1, Intermediate Q1

The Hrossa of Malacandra make quilts of hexagonal patches in an overall triangular shape. The patches are coloured red, blue or green.
Each hexagon and the two beneath it must be the same colour or three different colours.





How many blue patches are there in the quilt below?



(A) 4 (B) 5 (C) 6 (D) 7 (E) 8

ii) *Logic*

These are engaging multiple choice questions early in a paper. They can require quite rigorous reasoning and case analysis.

Magic Carpet is an attractive question and, according to its proposer, "This is the one the students will be talking about afterwards."

Although in the context of the paper it is a logic question, it invites further exploration: "Can we generalise the solution to many members?" "What if there is an odd number of members?" As such, it is a good candidate for a training question for the AIO.

Magic Carpet: 2012 Senior Q4

Anna, Beth, Coral, Dianne, Emma and Francis are going camping on an offshore island. They are using their magic carpet to get to the island. The magic carpet can only take 2 people at a time, so there will need to be 9 trips, 5 across carrying 2, and 4 returning carrying 1.

Flying on a magic carpet can cause air sickness, so the speed of the carpet is determined by the rate at which the more susceptible passenger can travel.
The times that Anna, Beth, Coral, Dianne, Emma and Francis can travel one way without queasiness are 1, 2, 3, 4 and 5 minutes respectively.
What is the least time, in minutes, required to fly all members to the island?

(A) 15 (B) 16 (C) 17 (D) 18 (E) 19

iii) *Analysis*
Many analysis questions require students to determine the number of operations a particular algorithm requires on a set of data. This gives students an introduction to complexity analysis of the algorithm. Another popular analysis question asks students to count the number of different routes through a network. Most analysis questions are multiple choice, although some are three-stage.

Guessing Game is a typical analysis question. Students discover the binary sort technique.

Guessing Game: 2009 Senior Q6

Ben's grandfather said to him "I have thought of a 3 digit number for you to guess. Each time you guess I will say 'Too high', 'too low' or 'correct'. You have 9 guesses. By then you should know the number."
Ben's first 8 guesses were 600 (too high), 300 (too low), 450 (too high), 360 (too low), 405 (too low), 427 (too high), 416 (too high) and 410 (too high).
By this time Ben knew that the number must be between 406 and 409. But he only had one guess left and so could not be sure that he would know the number after his last guess.
Ben's guessing strategy was flawed. After which guess was it no longer possible for him to be sure of knowing the correct number after his remaining guesses, assuming that he used the best strategy for them?

(A) 600 (B) 300 (C) 450 (D) 360 (E) 405

iv) *Algorithms*
Algorithm questions are the heart of the AIC. About half of the multiple choice questions are algorithmic and they dominate the three-stage questions. All are optimization questions of one sort or another. Breadth first searches are popular, and when used in threestage questions students can be guided to discover the technique for themselves. Dynamic Programming and Two-Person Game questions are also common, and the problem setting committee takes delight in a good ad-hoc problem that requires its own special purpose algorithm.

Game is a three-stage task from the first AIC. The first diagram is easy to solve by inspection. As is the second. But even there the choice to move to the 10 then the 11 rather than the 2 then the 11 is the beginning of a breadth first search. The rather odd rule of halving the current score makes it harder to solve by inspection, and encourages an algorithmic approach.

Game: 2005 Senior Q13-15

You are playing a rather unusual game on a 4×4 grid, in which each square contains a number. You begin in the top left square of this grid, and you must travel to the bottom right square. The rules state that you must move either one square down or one square right in each turn.
To begin with you have a score of zero. Each time you move into a new square, you must halve your current score (rounding down if necessary) and then add the value of this new square. Your aim is to reach the bottom right square with the smallest score possible.
As an example, consider the following grid.

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

The smallest possible final score for this grid is 12, which is achieved as follows.

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

What is the smallest possible score for the following grids?

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

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

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

Golden iPods was used in both Intermediate and Senior papers, with different data sets. It remains one of our favourite Dynamic Programming questions.

Golden iPods: 2008 Intermediate Q13-15, Senior Q13-15

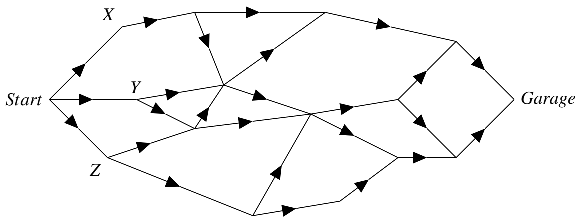
After years of research and parsecs of travel you have finally reached the third planet of Sol, ancient birthplace of humanity. You enter the great Jobs Repository and there is the object of your quest — the fabled golden iPods. You cast an expert eye over them, evaluating each. You cannot take them all. Your research indicates that taking any two adjacent iPods will cause the immediate destruction of the planet, you included. But you wish to maximise the value of the iPods you take.
For instance, if there were five iPods with values `5 6 3 1 2` you would take the 1st, 3rd and 5th, with a total value of `10`. If their values were `5 8 2 2 9` you would take the 2nd and the 5th with a total value of `17`.
For each set of iPod values, determine the maximum total value you can get without taking adjacent iPods.

```
1 3 1 3 4 4 4 3

1 4 4 5 8 5 3 4 1

4 3 2 5 8 6 2 2 3 2 2 2 1 1
```

The map in the two-person game Map Game is large enough to warrant a systematic approach to the solution.

Map Game: 2011 Senior Q4

You and a friend are playing a rather unusual game with a model car and a road map. You take it in turns to move the car along one section of a road on the map. (All roads on the map are one-way, left to right.) You win if you force your friend to move the car to the garage.



For the map above, it is your turn to go first.
You can be sure of winning if your first move is to

(A) any of X, Y, or Z
(B) X or Y, but not Z
(C) X or Z, but not Y
(D) Y or Z, but not X
(E) Y, but not X or Z

Robot Librarian is a three-stage question with an ad-hoc algorithm. The first data set is small enough for students to fiddle, and, hopefully, to discover the algorithm.

Robot Librarian: 2014 Intermediate Q10-12

The school has acquired a robot to help the librarian. It can sort books on shelves, but only by taking a book out and placing it at either end of the shelf.
For instance, if the books `A B C` were on a shelf in the order `B A C` they could be sorted by moving the `A` to the front. If they were in the order `C B A` they could be sorted by moving the `C` to the end and then the `A` to the front, (or the `A` to the front and then the `C` to the end).
Each of the following lists represents a shelf of books. For each shelf what is the smallest number of books the robot must move to sort the books into alphabetical order?

`F C A B D E`

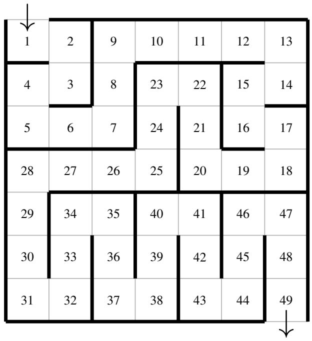
`D E C A F B G H`

`D F A E C I G B J H`

Putting the numbers in the cells in Maze Shortcut made it somewhat easier to find the algorithm, but not doing so could have turned it into a bit of a time sink.

Maze Shortcut: 2013 Senior Q1

The way through the maze below passes through all 49 cells.



How long is the shortest path made possible by removing one wall of one cell?

(A) 15 (B) 17 (C) 19 (D) 21 (E) 23

The algorithm in Aesthetic Skyline is not too difficult to find, but it caused some debate in the committee.

Aesthetic Skyline: 2014 Senior Q4

The council's planning committee has decided that the buildings in a new development should be arranged to provide an aesthetic skyline. This means that adjacent buildings should differ in height as much as possible. For example, consider the two arrangements of five buildings with heights of 8, 4, 3, 2 and 1 floors below:

The arrangement on the left has a total height difference of $4+3+1+1=9$ floors, whilst that on the right has a total height difference of $4+7+2+1=14$ floors. (But better arrangements can be found.)
A new development consisting of eight buildings with heights of 2, 3, 5, 2, 9, 6, 5 and 1 floors is planned.

What is the maximum total height difference for these eight buildings?

(A) 28 (B) 29 (C) 30 (D) 31 (E) 32

The concern was that the proof of optimality is not easy and some of the better students could spend time looking for a better solution. Readers are invited to admire the cute diagrams. All diagrams are written in the Tikz package in Tex

Golf can be solved by a nice ad-hoc algorithm, easily discovered by students. It was used as a three-stage task in the Intermediate paper, and as a multiple choice question (with a smaller data set) in the Junior. If it was extended to three players, it could be expressed as a Transportation Problem.

Golf: 2013 Junior Q6, Intermediate Q13-15

Yani and Na Yeon are entering as a team in a golf match. Their match score is calculated as follows. For each hole they must choose to include either Yani's score or Na Yeon's score. Overall, an equal number of scores must be chosen from each player. For example, if there are 10 holes in a game, 5 of Yani's scores and 5 of Na Yeon's scores must be included.
The aim is to make the combined score as small as possible.
For instance, suppose there were four holes and the scorecard was as follows:

Hole	1	2	3	4
Yani	4	1	4	5
Na Yeon	2	3	4	2

The smallest match score, 9, would be achieved by taking Yani's score for holes 2 and 3, and Na Yeon's score for holes 1 and 4.
For each of the scorecards below, what is the smallest possible match score?

Hole	1	2	3	4	5	6	7	8
Yani	4	1	3	2	3	2	4	5
Na Yeon	3	2	2	3	4	1	5	6

Hole	1	2	3	4	5	6	7	8	9	10	11	12
Yani	2	1	2	2	5	6	1	2	2	2	3	1
Na Yeon	4	2	3	5	4	5	4	2	6	5	2	4

Hole	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Yani	3	5	4	3	5	5	6	4	7	3	5	7	2	1	2	4
Na Yeon	1	2	1	1	5	1	2	7	3	3	2	4	1	3	3	3

v) *Other Types*

Not all questions fit into the above categories. Some questions straddle categories, whilst some pattern matching questions do not fit into any of the above categories.

Alphabet Sort is a three-stage pattern matching task. The first data set allows the students to discover the pattern on a smaller amount of data. The last data set invites students to work backwards.

Alphabet Sort: 2008 Junior Q10-12

A sorting program does not understand about numbers. It treats all digits as letters, so that the numbers 10, 11, 100, 101, 111 would be sorted as 10, 100, 101, 11, 111.

- If the numbers 1, 2, ..., 99 are sorted, what is the 45$^{\text{th}}$ number?
- If the numbers 1, 2, ..., 999 are sorted, what is the 120$^{\text{th}}$ number?
- If the numbers 1, 2, ..., 200 are sorted, what is the 195$^{\text{th}}$ number?

3. Some Practicalities

Both the AMC and the AIC include multiple choice questions, but their use is primarily to enable automatic marking. In a traditional multiple choice question, a student who does not know the answer may be able to eliminate some options, thereby increasing their chances of guessing correctly. For example in

The capital of Lithuania is

(A) London (B) Sydney (C) Vilnius (D) Belgrade (E) Riga

most Australians would be able to eliminate Sydney and many would be suspicious of London, so the chances of guessing correctly would increase to one in three. Clark and Pollard (2004) have designed scoring systems to reward partial knowledge with partial marks. In the AIC and the AMC, however, there is no partial knowledge and there are no obvious distractors to eliminate. Students solve the problem and check to find it on the list.

A further decision in the AIC was whether to penalise incorrect answers. This was done in the AMC until 2004 in an effort to deter guessing. This was only partially successful. Studies on the AMC data by Atkins, et al. (1991) indicated that in years 7 and 8, girls were more likely to guess than boys, but the situation was reversed in years 11 and 12, and in a competition with several hundred thousand entries, odd results did very occasionally occur. They were identified as a student who did poorly in previous years who suddenly came out as a prize winner. Penalties are not used in schools and were unpopular in the AMC and were dropped in 2005. Guessing was addressed by including questions whose answers were a number in the range 0–999. In the AIC there are no penalties and three-stage questions have 0–999 answers.

Unlike in the AMC, calculators are permitted in the AIC. Whilst accuracy is important, the committee decided that students who found the correct algorithm should not be penalised for an arithmetic mistake, especially as programmers would have access to them when developing and testing their algorithms. In multiple choice questions, where it is possible the options are two or more apart rather than being contiguous.

Another technique used in analysis questions is to give a range of numbers in each option.

4. Moderation

The AIC is set over one weekend by the problems committee. The chair of the committee then constructs the data, invents the story if necessary, typesets the data, writes the solutions and distributes the papers to the committee for moderation. The committee includes two teachers. Later, there is a second round of moderation by teachers. They ensure that the questions are at the right level and the language is accessible to the students. Examples of questions resolved during moderation include “Can we assume that students know what a vowel is?” (answer “No”) and “Can we assume that students will know N, S, E and W?” (again answer “No”). The first AIC was set by three academics in about two weeks, communicating by eMail. Moderation was done by university colleagues. To our relief there were very few problems, but we did stumble over one question where we defined clearly, unambiguously and concisely what we meant by a syllable. Students ignored our definition and used their own ideas. Teacher moderators would have prevented that.

5. Where to Next

There is no doubt that there is a growing concern in many countries that algorithmic and computational thinking is under-represented in the school curriculum. Whilst it used to be a part of some senior computer science courses, these have now become primarily application based, and the need for programming skills is much reduced. In Australia, this has been addressed by the introduction of a Digital Technologies strand as a part of the Technologies Learning Area. Whilst useful as a statement of intent, this will be hard for schools to implement without support and resources. Students in Years 5 and 6 are expected to be able to Design, modify and follow simple algorithms represented diagrammatically and in English involving sequences of steps, branching, and iteration (repetition), whilst by Year 8, they should Implement and modify programs with user interfaces involving branching, iteration and functions in a general-purpose programming language. [Australian Curriculum – `http://www.australiancurriculum.edu.au/technologies/digitaltechnologies/Curriculum/F-10`]

This is a very long way from what is currently happening in schools. In this context, the resource base provided by AIC questions which introduce algorithmic thinking can play an important role. This has led the AMT and the problems committee to consider the implementation of an additional competition level for Upper Primary (Years 5 and 6) students and this level will be introduced in 2015. We have also made the decision to move the competition into an on-line format from 2015. Hopefully, this will make it much easier for schools to access and implement, and it seems an appropriate format for a competition designed to encourage students to learn programming. This also opens up the possibility of marketing the competition internationally. There is currently a dearth of entry level informatics competitions and none, for instance, which have yet penetrated the US market, where the same kinds of curriculum demand are beginning to appear.

Such marketing may lead to a need to give the competition a more international name, though no decision has been taken on this at present.

Currently, Australias stocks in Informatics are high. We have just hosted a successful IOI (Brisbane 2013) and our results in IOI are very strong, particularly when compared with our population. This is due, in part, to programs (including the AIC) which allow us to identify and develop students with potential. However, in a world with an increasing demand for technological literacy, we need to encourage more schools and students to develop the skills required to cope with such demands and we believe that the AIC represents an important starting point in this process.

References

Atkins, W.J., Leder, G.C., O'Halloran, P.J., Pollard, G.H., Taylor, P.J. (1991). Measuring risk taking. *Education Studies in Mathematics*, 22, 297–308.

Burton B.A. (2010). Encouraging algorithmic thinking without a computer. *Olympiads in Informatics*, 4, 3–14.

Clark, D. (2006). The 2005 Australian Informatics Competition. *The Australian Mathematics Teacher*, 62(1), 30–35.

Clark, D., Pollard, G. (2004). A measure of the effectiveness of multiple choice tests in the presence of guessing: Part 1, crisp knowledge. *Mathematics Competitions*, 17(1), 17–33.

Clark, D., Pollard, G. (2004). A measure of the effectiveness of multiple choice tests in the presence of guessing: Part 2, partial knowledge. *Mathematics Competitions*, 17(1), 34–47.

D. Clark was a committee member of the Australian Mathematics Foundation for 20 years, and has been a member of the Australian Informatics Olympiad Committee since its inception in 1998. He was treasurer for the first 10 years and was deputy team leader of the Australian teams at the IOIs from 2001–2003. He is currently the chair of the AIC problems committee, a post he has held since 2008.

M. Clapper has been a teacher of mathematics and computer science for many years, as well as a school principal. He has been a member of the AMC Problems Committee for 12 years and is currently chair of that committee. He commenced his current position of Executive Director of the AMT in January 2013.