NOTES ON A POSSIBLE ARTIFICIAL INTELLIGENCE GCE/A-LEVEL SYLLABUS

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This is a slightly reformatted version of an online HTML document.
http://www.cs.bham.ac.uk/~axs/courses/alevel-ai.html

CONTENTS

INTRODUCTION

This is a *first draft* set of notes on a possible set of syllabus proposals for teaching Artificial Intelligence in Schools. This could be seen as an alternative to proposals for teaching Computer Science in schools.

A typical Computer Science syllabus would take a 'bottom up' approach in which an understanding of computing is based on understanding of some of the important features of computers and aimed at producing people with the ability to develop and to think about computing systems that meet important current and future practical needs.

The AI proposals presented here are intended to *complement* such a syllabus by offering a type of education that would be attractive to a different kind of student, such as might be interested in the study of philosophy, psychology, language, social science, biology, or mathematics. It would adopt a more 'top down' approach, by introducing such students to 'higher level' ideas such as the notion that there are various kinds of information processing, some of which occur in nature, e.g. in all animals, including microbes and humans, whereas others occur only in man-made machines. This opposition would lead to the challenge of producing machines that exhibit more of the capabilities that are characteristic of humans and other animals.

Such a syllabus should introduce

- The high level goals of AI and Computational Cognitive Science

  > Recently comprehensively surveyed in a two volume book by Margaret Boden 'Mind as Machine: A History of Cognitive Science' (OUP 2006) briefly described here.
  >
  > There will be BBC Radio 3 programme presented by Margaret Boden on Sunday 18th March 21:45 GMT: The Sunday Feature: Mind as Machine.

- Some of the techniques and programming languages that have been developed in pursuit of those goals
- A brief introduction to some of the practical achievements of AI (including its growing importance in computer games and other entertainments)

  > A vast source of information about that, and other things, is available at this web site http://www.aaai.org/aitopics produced by the Association for the Advancement of Artificial Intelligence (AAAI, previously known as the 'American Association for Artificial Intelligence' - the name has recently changed in view of the international spread of membership and activities.)

- Various kinds of challenges to AI such as philosophical and empirical arguments claiming to prove that the goals are unattainable, and attempts at rebuttals
- Ethical arguments related to whether the goals should be pursued and what the social and ethical consequences would be if they were achieved.

An example of the difference between the two kinds of syllabus is that whereas a Computer Science syllabus may start its programming component with work on logical and arithmetical operations, the proposed AI syllabus would begin with list-processing programs using a high level AI language providing pattern matching capabilities used to implement simple kinds of 'natural language' processing, such as generating and later parsing sentences, and then making plans, solving puzzles, and perhaps doing some learning. Some schools might wish to introduce AI teaching based on programming physical or simulated robots, though that should be an option rather than a requirement.

What is artificial intelligence (AI)?

AI is a (badly named) field of enquiry with two closely interrelated strands: science and engineering.

- The scientific strand of AI attempts to provide understanding of the requirements for, and mechanisms enabling, intelligence of various kinds in humans, other animals and information processing machines and robots.
- The engineering strand of AI attempts to apply such knowledge in designing useful new kinds of machines and helping us to deal more effectively with natural intelligence, e.g. in education and therapy.

AI is inherently highly interdisciplinary because all kinds of intelligence, whether natural or artificial are concerned with subject matters that are studied in other disciplines, and the explanatory models of natural intelligence have to take account of and be evaluated in the disciplines that study the natural forms.

Further information about the scope of AI is provided in an accompanying document: http://www.cs.bham.ac.uk/~axs/courses/ai-overview.html

NOTE

Like Alan Turing, in 'Computing machinery and intelligence', *Mind*, 59, pp. 433--460, 1950, I believe attempting to define 'intelligence' is a complete waste of time. We can collect many different examples of competences displayed by humans or other animals, and examples of challenging biologically-inspired behaviours required in future machines, and we can investigate requirements for modelling or replicating them without needing to draw any definite line between those that are and those that are not intelligent. We may find it useful to subdivide the cases in terms of either their capabilities, or the mechanisms required, or the kinds of information they use, or their potential usefulness in various contexts, and those divisions will be much more interesting and useful than any binary division based on a pre-theoretical concept like 'intelligence'.

Why would a student choose to study Artificial Intelligence?

The collection of course descriptions below is aimed at students who are interested in finding out how important ideas associated with the development of computer-based systems are relevant to the broad study of naturally occurring information-processing systems, and to the development of new machines with human-like or animal-like capabilities.

By taking this course such students will not only learn how to design, test, analyse, and compare working computer models of various kinds, but will also learn about their broader significance in helping us understand such diverse phenomena as human use of language, learning, visual and other forms of perception, problem solving, creativity, and also some of the evolutionary processes that produced them and some of the kinds of behaviours found in other animals. They will also be introduced to some of the practical applications of these techniques, e.g. in medical diagnosis, in computer games and in new forms of entertainment, as well as to philosophical and ethical debates related to these ideas.

The syllabus is **not** specifically aimed at students who wish to go on to higher education courses in computing or employment as computer developers or advanced computer users, though it may help such students. It may also be useful for students who wish to study other subjects at University, such as psychology, biology, linguistics, philosophy, engineering, or management, where it may be useful to evaluate current achievements and limitations of Artificial Intelligence and requirements for future applications of AI in those disciplines.

Students following this syllabus do not require any prior knowledge of computing, though it will be helpful to have basic familiarity with keyboard, mouse and text-input. A great deal of the work will involve typing text into a computer and reading textual output, and students who find that difficult will need special help. The course does not require specific mathematical skills though logical and mathematical potential will be very useful, and there will be opportunities to use and develop such capabilities. For example, learning AI will inevitably involve learning some formal logic and set theory (both of which can be learnt on-the-job), and study of complexity issues can be used as a basis for teaching students about combinations and permutations. Requirements for programs with graphical interactions can be used to teach students about coordinate systems and some linear algebra. The most important prerequisite is a liking for solving problems with an intricate structure, such as crossword-puzzles, sudoku, or Rubik cubes, and a strong desire to understanding how complex things work.

High level overview of the units

The syllabus will be made up of four units, the first two of which, taught over one year, could form an AS-syllabus, and when supplemented with the remaining two, taught in the second year, could form an Advanced-level syllabus. This is a first draft specification, subject to revision. It may be better to split some of the units into smaller, separately assessed components.

- **Unit 1:** Introduction to AI programming: building blocks
  Using simple, idealised models and games, students learn to represent aspects of the world and rules of behaviour in list structures, using pattern matching where appropriate. They will learn how to build various kinds of procedures for constructing, comparing, analysing and interpreting various kinds of symbolic structures, in the context of programs that analyse or generate sentences, hold simple conversations (initially Eliza-like, then more knowledge-based), draw pictures, explore simulated locations made of rooms, doors and corridors, make simple plans, solve problems, and play games, where appropriate using pre-built libraries to provide some of the building blocks.

  The programming techniques will make use of standard building blocks enhanced with AI mechanisms (e.g. use of local and global variables, conditionals, loops, recursion, case-constructs, along with pattern matching and rule-based programming). Simple AI toolkits may be used to implement concurrency, e.g. in simple adventure games or simulated robots or animals. A basic introduction to logic programming will be included, using Prolog to manage and interrogate a very simple database.

  The examination will consist of two parts, an internally assessed group mini-project chosen by students working in groups of two or more, and an interactive computer-based based test of understanding of a variety of programming constructs used in the course.

- **Unit 2:** History, philosophy, ethics and social implications of AI
  The examination will consist of two parts, an on-screen test (or possibly an examination-room written test) of knowledge of history, goals, progress, limitations and challenges to AI, and an internally assessed essay on some some aspect of the philosophical, ethical, social, or practical implications of

AI. For example the students should have a basic understanding of the similarities and differences between symbolic AI, connectionist AI, and evolutionary computation, without, at this stage, having learnt how to build connectionist or evolutionary programs. They should be able to answer simple questions about the importance of representations, algorithms and architectures in AI systems, and the recurring problem of combinatorial explosions (easily illustrated using some of the examples in Unit 1). They should know about some of the ambitious and controversial things being attempted in AI (e.g. attempts to give machines emotions), and understand some of the conceptual problems in defining such goals and evaluating progress, as well as some of the ethical problems.

- **Unit 3:** Advanced AI programming: designing integrated systems
  Students will build on the techniques in Unit 1 and attempt implementations inspired by some of the concepts introduced in Unit 2, building more complex AI examples using the materials from Unit 1 and also learning both how to build simple trainable neural nets and simple evolutionary programs, using pre-xisting libraries as building blocks where appropriate. The work will include both developing programs that check a solution to a problem (e.g. checking a proof in propositional logic, or a plan to achieve some goal), and also programs that produce the solutions, e.g. finding a proof or plan, using appropriate representations and search techniques. Finally they will learn how to combine multiple components that work together in an integrated architecture, possibly performing tasks concurrently, e.g. control of movement, perception, planning, communication and generation and evaluation of new motives. Students will start learning to think about how to reduce combinatorial complexity, and some of the tradeoffs between clarity and efficiency of programs.

  There will be considerable emphasis on prior documentation of high level requirements as well as designs, and on analytical or empirical comparisons of alternative solutions, and documentation of weaknesses and limitations of initial solutions to problems. The examination will consist of an on-screen assessment of understanding of various aspects of AI programming, including some tests of understanding of programming concepts, ability to describe and fix bugs, ability to comment on design descriptions or architecture diagrams, and ability to complete some nearly working programs.
  (Is all that feasible in the time available?)

- **Unit 4:** AI Project (internally assessed with external moderation?)
  Students will work in groups of two to five on an AI project on a topic of their choosing (approved by teachers) or selected from a list of possibilities provided by the examination board, meeting a set of published requirements for required kinds of complexity (e.g. combining at least two types of AI programming), based on the contents of units 1 and 3, and the need to illustrate some of the concepts introduced in unit 2. They will produce a group report on which the marks will be shared, and in addition all students will produce individual reports explaining their contributions to the project and providing their evaluation of their contribution as well as their evaluation of the whole project. Every report must include an analysis of limitations of the current program and some of the further developments that are possible.

  It would be desirable to allow such projects to include use of physical robots. However there are considerable extra costs in doing this and it may be best to wait for the new syllabus to get off the ground, with expertise developing and spreading across schools for a year or two before any special effort is made to introduce robotic teaching. Alternatively pilot schemes could start in parallel in a small subset of selected schools where there is already appropriate expertise and enthusiasm.

NOTE:
I do not know whether typical school circumstances and examination-board arrangements allow the possibility of such group projects. However the multi-level educational value of working on group projects is so great that if it is at all possible within the resources available, it should be allowed.

CAVEAT: VERY FIRST DRAFT

THE ABOVE IS A FIRST DRAFT (BRAIN-DUMP) SET OF IDEAS AND SUBJECT TO MUCH REVISION IN THE LIGHT OF CRITICISMS AND COMMENTS. IT IS INTENDED THAT THE SYLLABUS SHOULD ALLOW TEACHERS SOME INDEPENDENCE AND CREATIVITY SO THAT THEY CAN TAILOR THEIR TEACHING TO THEIR OWN EXPERTISE AND INTERESTS, WHILE CONFORMING TO THE SPIRIT OF THE SYLLABUS.)

Some practical challenges and possible (initial) solutions

There are several practical problems that will have to be addressed if this proposal is to be implemented.

- **Too few teachers**
  There are very few teachers who know enough about AI and AI programming to be able to teach such a course. So this option will have to be introduced gradually, in schools where there is at leas enthusiasm for the idea, and possibly some expertise. (E.g. see what Marcus Gray did, described below). It will probably be necessary for universities that already teach AI to offer conversion diploma or MSc courses to enable school teachers to acquire knowledge and skills required to start teaching these units. The second two units will, of course, not be taught until after the first two have been taught for a year, and that will help.

  It may also be possible to provide grants for experienced AI teachers in higher education institutions to take leave for several months or a year, to work with one or a group of schools wishing to set up this kind of course. Funding for a few post-doctoral fellowships could be extremely effective. (Would funding agencies like Leverhulme be interested? Could EU funding be found?)

- **No tools and administrative expertise**
  Very few, if any, schools will have computing facilities with suitable AI software installed or the expertise to install and maintain it.

  A solution that has many advantages is for the teaching to make use of remote servers, e.g. managed by university departments that already provide such facilities for their own students. They will need some extra resources to provide the required support, though initially numbers and demand will be low. One advantage of the use of remote shared servers will be increased possibilities for mutual help and collaborative projects straddling more than one school, and for students and teachers to be able to do work out of hours.

For example my department has been teaching AI at introductory and advanced levels for many years using software and introductory and advanced teaching/learning materials that could easily be made available remotely, as they are already for our own students. There will be several other such departments in the UK.
The idea of using remote servers for school computing is discussed in more detail in
http://www.cs.bham.ac.uk/research/projects/cogaff/misc/compedu.html

- **Costs**
  The costs of providing training for teachers, possibly new terminals and networking facilities, and developing an initial set of course materials and sample assessments would have to be met by an initial government grant of some sort. I have not really attempted to work out details, but I suspect an investment of about £2M over the first three years could produce major long term educational and economic benefits.

  1. Up to 40 school teachers who already have considerable programming expertise could be given opportunities to attend two one week residential AI summer schools with facilities provided for long distance study and practice in between. The courses would be taught by at least 4 AI experts. Systems administrators at existing AI centres would need to do some extra work and perhaps two or three extra dual cpu PCs, or one multi-cpu PC added to an existing computing service to support remote access by the teachers. (The main requirement for coping with the load would be memory. For AI development systems with shared code segments used interactively I suspect 4GB would easily support 40 trainee teachers learning about symbolic AI programming.) The AI experts and a subset of the teachers would also collaborate on producing a more detailed syllabus.

     Possible cost for an initial experiment, including travel, accommodation, equipment, and fees for the experts could be about £100,000, or significantly more if the courses included introductions to AI robotic programming using robot hardware. (I suspect that would be better left to a second wave of teacher training.)

     This experiment could be repeated at least once a year, with growing numbers of school teachers. Some teachers might get grants to attend longer, more substantial AI courses, e.g. a six months diploma course or a one year MSc course.

  2. In parallel with that, some AI graduates might be tempted into school teaching. It might be a good idea to provide scholarships/studentships for AI MSc courses and PhD courses for students who wish to commit themselves to teaching computing AI in schools.

  3. A possible later spin-off could be proposals for introducing AI courses including programming as an entertaining and challenging way of learning about computing, mathematics, language and philosophical thinking for younger children. This might lead to a requirement for a more advanced version of the courses available a later stage, and for more advanced university degree courses for students who start with AI knowledge and expertise gained at school.

- **Declining interest in science and intellectual challenges**
  This is a general problem that may defeat all attempts to raise academic standards in schools and universities. On the other hand it is possible that novel features of AI courses in schools, especially if they include robotics, may help to generate interest in intellectual challenges.
- **Comparison with Nuffield Science teaching**
  It has been pointed out to me that the proposed syllabus has much in common with the Nuffield approach to science teaching, which has received much praise but can also cause great difficulties in under-resourced schools, or when teachers are not up to the challenges of encouraging students to think independently. See http://www.nuffieldcurriculumcentre.org/

These problems and possible solutions are discussed further on this web page: http://www.cs.bham.ac.uk/research/projects/cogaff/misc/compedu.html

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Background to this proposal

This proposal has the following influences:

- **Concern about falling numbers**
  Much concern has been expressed recently about the fact that too few school-levers regard the study of computing as a subject of any sufficient interest to tempt them to apply for a computing degree course: they think of learning computing as just learning to use tools, useful but of little intellectual interest. See:

  > 'Inspirational IT' by Nigel Shadbolt, BCS President
  > http://www.bcs.org/server.php?show=ConWebDoc.7860
  >
  > BCS: UK tech industry faces skills crisis Tom Espiner ZDNet UK, 17 Nov 2006
  > http://news.zdnet.co.uk/itmanagement/0,1000000308,39284764,00.htm
  >
  > Comment in Computer Weekly 18th Jan 007
  > http://www.computerweekly.com/Articles/2007/01/18/221254/shortage-of-graduates-threatens-future-of-uk-it-sector-warns.htm

- **Specification of AI for QAA benchmarking document for CS**
  I was a member of the CPHC panel appointed by the UK Quality Assurance Agency in 1999 to produce a benchmarking document for use by teams inspecting departments of Computer Science. I was asked to produce a short definition of Artificial Intelligence, for use in the benchmarking document, along with a more detailed explanation of the scope of AI. That document on AI is still available at http://www.cs.bham.ac.uk/~axs/courses/ai.html.

  A slightly more up to date version is here http://www.cs.bham.ac.uk/~axs/courses/ai-overview.html

  > NOTE:
  > The final QAA benchmarking document for Computer Science (published in 2000) is available at
  > http://www.qaa.ac.uk/academicinfrastructure/benchmark/honours/com

puting.pdf

Although I am listed as a member of the panel responsible for the report, I felt then (as did some others) that it did not make sufficient allowance for a strongly theoretical degree with a high mathematical content permitting a theoretical project at the end.

- **A 30 year old vision of potential for AI in education**
  Over many years, starting around 1975 I have been involved in teaching AI at various levels ranging from a 'preliminary' non-specialist undergraduate AI course available to Arts and Social Science students to PhD research in AI and Cognitive Science. I became convinced in the 1970s that an introduction to AI could be an important part of a general 'liberal' education teaching students to think in new ways about structures, processes and their interactions, including mental processes such as learning, thinking, wanting, having emotions and understanding or composing sentences in a human language. Unfortunately, instead of taking this opportunity governments, industry, parents and schools succumbed to the temptation of regarding computing as merely a new technology to be taught to everyone as something to be used, and to a few as something to understand and develop. I believe that is the *main* cause of the lack of interest in computing as a subject for student at university level, now bemoaned by both industry and academe, though the cause is usually not mentioned.

  For further discussion of the issues see
  - http://www.cs.bham.ac.uk/research/projects/cogaff/misc/compedu.html

    Why Computing Education has Failed and How to Fix it
    (A message posted originally in November 2006).
  - http://www.cs.bham.ac.uk/research/projects/cogaff/misc/gc-ed.html
    Education Grand Challenge: A New Kind of Liberal Education Making People Want a Computing Education For Its Own Sake
    March 2004

  The vision I have been presenting overlaps with that in Jeannette Wing's paper 'Computational Thinking', in *CACM* vol. 49, no. 3, March 2006, pp. 33-35, available here:
  http://www.cs.cmu.edu/afs/cs/usr/wing/www/publications/Wing06.pdf

- **Some early experiments**
  The feasibility of the sort of thing proposed here was demonstrated nearly three decades ago when Marcus Gray installed a copy of the Sussex University AI teaching environment on a PDP11 computer running Unix at Marlborough college and taught AI using two AI programming languages. He and a colleague reported some of their experiences in

  'POP-11 for everyone' by Marcus Gray (pp. 262--271)

  'Creating a "good" programming language for beginners' by Michael Coker (pp. 282--299)

  in *New Horizons in Educational Computing*, Ed. Masoud Yazdani, Ellis Horwood Series In Artificial Intelligence, John Wiley, Chichester, UK. 1984, ISBN:0-470-20022-7

  The book also contained my own paper 'Beginners need powerful systems', also available here.

NB:
I am not saying there were no other demonstrations of feasibility. This is the only case of which I had first hand knowledge though I know there were scattered experiments going on in other places, though at that time I believe very few had the good fortune to use a sophisticated AI learning environment available during and out of hours to school children.

Overview document on AI

An associate web file elaborates on the brief definition of AI given above. http://www.cs.bham.ac.uk/~axs/courses/ai-overview.html

It is broadly based on the document on AI produced for the QAA benchmarking panel in 1999, available at http://www.cs.bham.ac.uk/~axs/courses/ai.html which was informed by consultation with university teachers and researchers in AI in the UK.

It's purpose is to provide a reminder of the scope of AI that can inform the more detailed design of a syllabus. However, many of these topics are too difficult to be included in a school syllabus, and are listed merely for information.

Additional information

The Association for Computing Machinery has a list of sub-fields of computer science, which changes from time to time. Several versions are available at http://www.acm.org/class/

It is not updated often, so it is now out of date and should be treated with caution.

AI Organisations

There are two main UK AI organisations.

The Society for the Study of Artificial Intelligence and Simulation of Behaviour, claims to be the oldest AI society in the world. See http://www.aisb.org.uk/

The British Computer Society Specialist Group on Artificial Intelligence (BCS-SGAI) has a more applied focus, though its seminars and annual conferences are very wide ranging. See http://www.bcs-sgai.org/

The main European AI organisation is ECCAI (European Coordinating Committee on AI), to which national AI organisations are affiliated. See http://www.eccai.org

The largest AI organisation is the Association for the Advancement of Artificial Intelligence (AAAI). Information about it is at http://www.aaai.org . It includes AITOPICS, a collection of Web pages (under continual development) that attempt to characterise the scope of

AI, and provide a steady stream of news about AI and its applications.

The major regular international conference on AI is The International Joint Conference on AI (IJCAI) held every two years since 1969. See http://www.ijcai.org

There are also many national Artificial Intelligence Societies, which organise conferences, and other activities.

There is a growing collection of web sites providing information about AI, some compiled by individuals and some by firms or organisations.

A document on AI for School Careers Advisers

A document was put together in 1998 for a conference of school careers advisers in England giving a more discursive overview of AI: http://www.cs.bham.ac.uk/~axs/misc/aiforschools.html

This includes pointers to several other sources of information about AI, including summaries by some of the founders of the field (e.g. Minsky, McCarthy), some textbooks, and UK universities known to be offering undergraduate degrees with AI in the title in May 1998.

This file maintained by Aaron Sloman
Last updated: 15 Mar 2007