WORKING NOTE AC65

Alan Creak
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DOES COMPUTER SCIENCE EXIST ?

BACKGROUND.

I collected the raw material for this note in late 1986 and early 1987. It's the "proceedings" of an extended interchange of electronic mail which I started with a deliberately inflammatory message questioning the integrity of "Computer Science" as an academic discipline.

Stimulated by a paper on the education of computists[1], I did a little work on the material in 1989 intending to publish it somewhere, but as usual time ran out. Rather than lose it, I've therefore collected it together here, almost - but not quite - raw, but available if needed. Who can tell ?

The material is cooked, or perhaps predigested, to the extent that I've tried to separate the contributions into three separate strands. They were not clearly distinguished in the debate, but hindsight suggests that the division is significant. It was interesting that the participants, by and large, didn't seem to have any clear idea of what science or engineering were, so there was quite a bit of discussion on that topic - particularly on "what is science". After that, people began to wonder just what computing was, anyway, and finally drifted back to the original topic. There are obviously links between the topics, but the threads are to some degree separate, and I think it's easier to read with the components teased apart. It's certainly clearer than it was at the time, when all the discussions were proceeding in parallel. I have presented each thread as alternating contributions from me and from other participants, which is roughly the way it went. I would have preferred a debate in which I played a less prominent part, but it didn't happen.

I'd expected that the debate would have been dominated by the academic members of the department, but, with a few isolated exceptions, all the contributions came from the graduate students or me. Perhaps everyone had more important things to do than try to find out what the department ought to be doing. (I could argue, and perhaps some day I will, that this attitude makes the point : because we don't think enough about what we do, we are rapidly becoming just the Department of Clever Schemes I warned against in my remarks.)

Dramatis Personæ :

ALAN : Alan Creak.
RICHARD : Richard Lobb.
JOHN : John Hosking.
LEE : Lee Booth
STEPHEN : Stephen Hawkins.
ROSS : Ross Clement.
LEX : Lex Miller.
BOB : Bob Doran

WHERE IT ALL BEGAN.

This is my initial statement :

> It has been suggested that the department's prestige within the Science Faculty is low, perhaps because the material we cover is not regarded as respectable science. Some historical figure or other is reported to have dismissed the opinions of the uneducated herd with the immortal words "They say. What say they ? Let them say !", and one is inclined to take a similar line in this instance. On the other hand, it has also been suggested that our lack of standing, should it exist, is not helping us to get our fair share of anything that might be going; so aloof superiority may not be in our best interests in the long run.
>
> So perhaps we had better think about what it is we do, what it is we claim to do, and what that which we do is. (Work it out.) If that gets us anywhere, phase 2 is to decide whether what we do is what we ought to do, and, if not, what that which we ought to do is.

Opinions, ideas, suggestions, comments etc. are invited. Rude ones will be ignored. Here are some inflammatory statements to start things off :

(These appear below at the beginning of the SCIENCE OR ENGINEERING section.)

My opinion, should anyone care about it, is that suspicions of "Computer Science" are all too often well founded. We don't know what we're doing : think of a sentence like "Chemistry is the study of what happens when atoms interact" which begins "Computer Science ...". The definition of chemistry isn't precise, but it says a great deal about the subject; can you do as well for computing ?

I think we try to mix together the engineering and science, without being careful to distinguish which is which. I don't think it matters that the subject has a foot in both camps; I'm more concerned that we ignore this sort of analysis of our discipline.

SCIENCE OR ENGINEERING ?

FROM ALAN : 1. Computing is not science, but a branch of engineering. A scientist tries to determine the behaviour and properties, and to infer the structure, of the essentially unknown natural world about us; an engineer begins with essentially known resources and studies how best to deploy these to solve problems. Computers and computing machinery are essentially known; they're certainly not part of the world of nature !

2. There is a part of the natural world which is a worthy object of scientific study, but it is only incidentally connected with computers. It is called (when it's called anything) something like "information"; it includes semantics, semiotics, and lots of other fields with names unfamiliar to me. Computers get into the act because they're the first machines we've invented which can make any sort of show of handling information; but the subject itself is much wider.

FROM RICHARD : Who's arguing?

REPLY : Thank you, Richard.

FROM JOHN : I think the arguments you are espousing can equally be levelled at subjects such as Physics where there has always been a "pure" versus "applied" battle - the geophysicists etc being "looked down upon" by the quantum physicists. Computer Science comes from a very STRONG theoretical background, for instance the work of Shannon on information theory and Turing and Von Neumann on computability theory etc state/answer fundamental questions of how the universe "works". There is as much "science" in this work as in any discipline.

REPLY : You could equally say that engineering is based on a very strong theoretical background of thermodynamics, electromagnetism, mechanics, etc. - and so it should be, or the machines wouldn't work, the bridges would fall down, and so on.

If you like information theory, that comes under my "science that's not about computing" heading. I have no quarrel with it, though my impression is that it's still in a fairly primitive state. It's a long way from being able to distinguish between a number of patterns of digits to the amount of information that's actually conveyed by the pattern.

Computability theory is a branch of mathematics, and as such says little enough about how the universe works - unless you study it as a psychologist. As I remember, it's connected with the universe through the Church-Turing hypothesis, which is that a Turing machine (and some other equivalent things) can compute any function which we normally regard as computable. Which is fair enough, but if you want it to be science you have to devise an experiment which tests the hypothesis. Suggestions ?

(No suggestion was forthcoming.)

FROM ROSS : In reply to John Hosking, Alan claims that engineering is based upon a very strong theoretical background, and therefore the fact that computer science is also based upon a strong theoretical background is neither here nor there. This is an oversimplification of John's argument. Computer science is based upon extending and developing this theoretical base, which is science. If it did not extend this base, then it would not be a science. If various engineering disciplines are also involved in extending their theoretical base then this is a scientific aspect of their discipline.

REPLY : Your definition of science is not the same as mine. I take science to be "natural science", which aims to explore the structures and mechanisms of the universe in which we live. The "theoretical base" is the collection of hypotheses which we currently hold to account for the things we observe. Purely logical or mathematical developments from that base don't necessarily tell us anything new; real advances come from experiments, which we have to perform because we have no other way of finding out the results. Computing doesn't fit into that pattern, because the universe is the computer, and we already know all about how it behaves. (And if it behaves in any other way, we call the *engineer* to mend it.)

In any case, I'm far from sure that "what computer scientists do" really does advance by working out the consequences of information theory, computability theory, etc. It certainly isn't obvious !

Can't we draw a strong analogy between a lot of what we do in computing and an engineer investigating, say, the combustion patterns within an engine's cylinder with a view to improving the engine's design ? No scientific development is normally involved, though scientific principles are used.

FROM ROSS : Alan also claims that computability and information theory are not parts of computer science. In this case he has completely ignored the argument (which he has NOT answered, apart from quibbling about "where do you draw the line?") that areas that are computer science are attributed to other sciences. Computability theory is a branch of mathematics, but it is also a branch of computer science. The same applies to information theory.

REPLY : I said that computability theory was a branch of mathematics, and as such not a science at all. See below. I said that I was happy enough to accept information theory as science, but that it wasn't primarily about computing. (I would qualify that statement about information theory if pushed, but it will do for now.)

It is certainly possible for branches of science to be connected with more than one of the standard scientific "subjects"; for example, thermodynamics is equally at home in physics and in chemistry. But that doesn't mean that you can grab together a set of topics which happen to be connected to (say) computing, and necessarily expect them to form a coherent discipline. That way, I could develop my other proposal[2] into the new subject of photocopier science. I understand that one can be awarded a degree in hamburgerology.

FROM LEE : Is maths a science?

I think we're safe in AI (although I suppose physicists don't consider psychology a true science). In a paper by Hayes he states something like:

> "Is naive physics a science? Who cares. It's important, difficult and fun"

This is probably a good philosophy.

REPLY : I think mathematics is more of an art form than a science. Is that relevant to the matter under discussion ?

Artificial intelligence : it depends on what you mean by "safe". If you want it to be science, you have to answer questions about what hypothesis you are testing, how you design an experiment to test it, what result you expect, and what it means if the result is something different. You can do that sort of thing if you're, say, trying to simulate the saccadic movements of the eye - but maybe that's psychology or zoology or something ? (See my reply to Ross's contribution.) If, on the other hand, you are trying to find a way to do X, then I think you're doing engineering.

Hayes's philosophy : Yes. As a personal philosophy it's great, and that's why I quoted the "let them say" thing in my original letter. But it's not guaranteed to go down well in the Science Faculty, particularly with people whose departments are diminishing while ours grows.

FROM ROSS : In reply to the dreaded Lee, Alan claims that he thinks that mathematics is an art rather than a science. Philosophers of science can show that all sciences can be reduced, through physics, to mathematics. If mathematics is not a science, this would seem to infer that the definition of science you have come up with is so restrictive as to exclude every human endeavour.

REPLY : I don't believe that philosophers of science can show any such thing. Without experiments, how can you know that the result of the mathematics bears any relation to what actually happens ?

FROM LEE : I suppose you consider the wonderful new discipline of genetic manipulation has strayed from the boundaries of science. However, if you consider it a science I think you might have difficulty claiming computer science is not.

REPLY : Yes.

FROM STEPHEN : I don't think computer science is a subset of engineering, rather there is an intersection set between the two.

How about this: computer science is the study of enabling computers to do work for us.

REPLY : Electrical engineering is the study of enabling electricity to do work for us ? It's difficult to see any difference in principle between these two statements.

FROM ROSS : Alan seems to have come up with a fairly convincing argument against Stephen's letter, except that his [Alan's] argument depends entirely (as do most of his arguments) on there being NO science involved in [electrical] engineering at all. Unless Alan proves this, showing a similarity between computer science and engineering does not show that computer science is not science.

REPLY : Whether or not there's no science in electrical engineering, it is still electrical ENGINEERING. If computing is like electrical engineering, then at least there's a case to answer. Perhaps I should make it clear that I don't believe that there are hard and fast lines between different sciences, or between science and engineering. In both cases, the distinction is largely a matter of the attitude of mind of whoever's doing the work. But I think it's useful to distinguish between the attitude of exploring the structure of the universe and that of using what we know to accomplish a set task. And I think that most of what we currently do in computing is directed towards getting things done.

WHAT IS COMPUTING ?

FROM ROSS : I have many times come across the attitude that computer science is merely teaching programming, and nothing else(*). Some people have thought that a masters' degree in computer science is nothing but writing a big programme, and some cannot understand what I am doing if I do not have a programme.

The point I would like to make is that to a certain extent this is true, and possibly some of the low standing is justified, for the following reasons:

(1) In stage one, people have to be taught programming. This would be equivalent to the English department having to teach the English language before it could start teaching literature etc. This cannot be blamed upon the department, it is a fact of life.

(2) I think that there is more emphasis on programming and practical applications than is appropriate for a "science" course. But then again if people are to be prepared properly for the types of employment they are likely to be working in then this is also necessary. computer science seems to be caught between the business community and the scientific community and cannot please both, and hence "loses standing" in the eyes of both.

Also there appears (to me) to be some unjustified prejudice on the basis that (I believe) many people's opinions on what computers can achieve is severely limited, and their ideas on what Computer Science is, are limited by this.

(*) "Do you mean to say you have to know how the ******s work!!" - A biochemist examining the piece of paper I was using as a dart.

REPLY : Computing = programming. I think this is a good point. It happens to other subjects, too - "Chemistry = stinks and bangs" did a lot of harm, but at least (most) members of the Science Faculty should by now be better informed. (Now it's "Chemistry = nerve gases and pollution".) But this brings us back to where we started, and it's why I wanted someone to come up with a short and snappy slogan.

Practical bits. There's nothing wrong in a science course being practical ! But I suspect you mean to question the ratio between the practical and theoretical parts. If so, I agree : it's very easy for many of our courses to become lists of "this is how you do X" recipes. (Yes, I do it too.) How do we avoid becoming a Department of Clever Schemes ?

FROM ROSS : Very important point: computer science, as I see it especially considering the subject of my thesis[7], is NOT ONLY the study of computers per se, but also the study of applications which are commonly associated with computers. Examples of these are natural language processing, information (as you mentioned), computational logic, etc. These applications are not a study of computers, but I think they are a normal part of computer science. I also think that because computer science is younger than many of the sciences it "overlaps", it is considered that these overlapping areas are not part of computer science, but of other sciences like physics, maths, and philosophy. For an example if the areas of Zoology that were not also classifiable as "cell biology" were removed much of the scientific research in zoology would disappear. (Zoology at above microscopic levels has been gone over very thoroughly.)

REPLY : Where - not to mention how - do you draw the line ? Do you include quantum mechanics ? accountancy ? video games ? I think you have to say something to the effect that we study the ways in which all these topics are handled so that we can refine the computational techniques used; but there's a great deal more to, say, natural language processing than we're ever likely to cover in a computing course. When the world was very young and I was still a chemist, I had no doubt whatever that the subject I was studying was chemistry - though I spent most of my time actually using mathematics or computing. Very little of my work could sensibly have been

studied by computists or by mathematicians, except perhaps as an isolated example of some specialised technique.

Which is to say : we are trying to find how to use our known resource to solve certain problems. Engineering !

FROM ROSS : In reference to my comment that there is a large overlap between computer science and other sciences. Alan has asked me "Where - not to mention how - do you draw the line ?". This is easy to answer, computer science is the area of science commonly studied by computer scientists.

REPLY : That may be an easy answer, but it's not very useful ! - unless, of course, you have an independent way of telling whether or not someone is a computer scientist. (Should there be such a condition, which I question.)

FROM ROSS : From the makers of "All science is either physics, or butterfly collecting" comes a new one. "All computer science is either artificial intelligence, or hacking". This is guaranteed to be just as correct, and just as offensive as the first.

REPLY : As everyone knows that physics is just a small corner of chemistry, I shall ignore the first quoted sentence above. But that raises the point : of what is computer science just a small corner ?

WHAT IS SCIENCE ?

FROM LEX : Of what is science just a small corner? What is science? What is art? Is the universe art?

If there is a creator then it is. If there is not a creator then the universe could still be considered art (many say that even randomness is art). So, science (being the study of the universe) could be the study of art. i.e. science is just a small corner of art.

But, as was said earlier, art is a useful tool of science, thus making art just a small corner of science.

By set theory, this could make science and art the same set (!).

Goodness knows where computer science comes in.

REPLY : I'll take this seriously.

The argument is disconnected, and open to criticism. "A is the study of B" doesn't imply "A is a small corner of B" (try A = astronomy, B = stars). Likewise "A is a useful tool of B" doesn't imply "A is a small corner of B" (try A = dentist's curved mirror, B = constructing small electronic circuitry).

Anyway, if your English is right, your set theory is wrong; for surely "just a small corner of" must correspond to "a PROPER subset of".

FROM STEPHEN : Friends of mine doing engineering (including electrical engineering) often comment on the large amounts of maths they have to do, but is maths science? I would have thought so but Alan looks at it as being an art. Is engineering a subset of art ?

REPLY : My judgments here have to do with the constraints under which the various activities are carried out. Science is constrained by what actually happens when you do experiments; an artist (it seems to me - here I'm guessing) is constrained by the limitations of whatever medium is concerned, and by the limits of imagination. Mathematics is not constrained by physical "reality", but has additional constraints of logic which must be satisfied - in a sense, logic is the medium of expression of a

mathematician. Engineers are certainly constrained by the real world, but also by the requirement that their constructions should work. I don't think that's a characteristic of art as such; perhaps it's something to do with a distinction between art and craft ?

FROM ROSS : Finally, there appears to be an opinion that a science must study something that exists in the "natural world", i.e., was not created by man. Whether or not computers were created by man, they do exist in the real world, and can be studied. While computer science could never be called a "natural science", I have not been given any reasons why this means that computer science is not a science of any type.

I'm not sure that I know the definition of science. What is it?

REPLY : See comments above on science. The point is that science is an attempt to solve a puzzle : how does the universe work ? If we study something we've made for ourselves, then there IS no puzzle - see comments above on calling the engineer. If we find that the thing we've built performs in some surprising way, then surely the surprise isn't in our machine, but in that on which the machine is working - which brings us back to the idea of information science, or whatever.

FROM BOB : If you have such a restricted definition of science then you are sure to win the debate. The term is a lot wider, as in "political science". I like the OD definition: "A branch of study which is concerned with observed facts systematically classified and more-or-less colligated by being brought under general laws, and which includes trustworthy methods for the discovery of new truths within its own domain." At the moment the idea of computer science being study of things to do with computers and computing is good enough (analogy with political science), there is photocopier science but it isn't so special that regarding it as an independent subject makes too much sense (though it could make a course or two). I suspect that computer science is evolving very quickly to the stage where we will be able to give a better definition but it will be complicated or so succinct as to be useless. Rather like a general definition of mathematics. Some of the sub-subjects will, of course, have much tighter definitions e.g. there is no doubt that logic-circuits is a branch of computer science the bounds of which are well known. Here we go out on a limb but if I had to guess I would think that the notion of an algorithm is the central theme of the subject (with description being regarded as an algorithmic process) :

Programming - designing algorithms.
Hardware for executing algorithms.
Numerical algorithms.
Data base description and access algorithms.
Algorithms for controlling robots in real time.
Mathematical theory of algorithms.
Data communications protocol algorithms.
Etc. etc. etc.

The distinction between computer science and maths is that the latter involves fixed truths that do not depend on the flow of time (which is the essence of an algorithm); even calculus reduces motion to a formula. Maths gets rid of time and sequencing, we are immersed in it. Notice that this puts information theory in with maths where you believe it belongs. Rabbit on, rabbit on.

REPLY : I'm not trying to "win the debate"; I just wanted to know how other people see things. I think my definition of science would go down reasonably well in the Science Faculty, though, whereas one which includes "political science" probably wouldn't.

The OD definition is fair enough, but what are the "observed facts" ? I argue that they aren't about computers as such, because there are no new facts to observe - in principle, we know all about computers before we start because we know exactly how they work. The facts may indeed be about computing, but that brings us back to informatics, or whatever you want to call it, and identifies computers as no more - and

no less - than the tools we use in our experimental work. Perhaps your emphasis on algorithms leads us the same way.

But I'm far from convinced that computing, whatever it is, can be reduced to algorithms, any more than physics can be reduced to mathematics. Physics leans heavily on mathematics, but somewhere someone has to do the experiments to get the results to which you can apply the mathematics. What are the experiments in computing ? Without them, I think it's difficult to justify classifying computing as a science.

I don't see that computing = mathematics + time, either. (Or, perhaps, it would be fairer to say mathematics + change.) That gets us into the Hoarey old topic of analysis of procedural algorithms - which is hard and messy, but clearly mathematics[3]. "All" mathematics needs to handle change is some appropriate axioms[4].

Reprise - SCIENCE OR ENGINEERING ?

FROM ROSS : Bob said [A definition of science is:]

> "A branch of study which is concerned with observed facts systematically classified and more-or-less colligated by being brought under general laws, and which includes trustworthy methods for the discovery of new truths within its own domain."

Plenty of experiments have been performed by computer scientists, some of which I know about include learning classification rules for chess end games, the automatic generation of expert systems, testing the accuracy of an expert system (P.U.F.F.) on real world problems, and measuring the average computation of algorithms on realistic data sets, Gordon debugging a programme, etc., etc. ..

Many "facts" have been learnt from these experiments, many of which have interacted with entities in the "real world". Why is this not science? Why is this engineering?

Also, "win the debate" is not a term I would apply to Alan's arguments. Alan has claimed that any part of computer science that cannot be fobbed off with a "non-science" argument is actually part of another science such as "mathematics", "philosophy", "information science". It has long been known that various scientific domains overlap to a great extent. Even if it can be claimed that (e.g.) the study of induction is a branch of philosophy, this is in no way evidence that it is not part of computer science.

> "Square that!" --- Winston Peters, MP.

Furthermore, a valid part of computer science is the attempt (which is going on) to design and implement systems capable of performing scientific research. If these systems are performing science under the direction of their creators then where does the science come in?

REPLY : All right. So the body still twitches.

All this exercise has at least helped me to clarify my thoughts, and I can attempt a summary like this :

> *In "computer science", the bits about computers aren't science,*
> *and the bits of science aren't (necessarily) about computers.*

Consider : how much does anyone (electrical *engineers* excepted) really care what machinery executes a programme ? So long as it's correct and reliable, what does it matter whether it's a Vax, or a Macintosh, or a Turing machine, or a pack of trained monkeys, or Father Christmas and his gnomes, or an IBM 4341 ? Hardly anyone even

uses a real machine : computists over the years have spent a great deal of time and effort hiding the real hardware under layer upon layer of software explicitly designed to make it look like something else.

The science (which I have never pretended doesn't exist) is about "information", or something. That was my second suggestion in the original letter - and it's still the one I prefer.

HINDSIGHT.

Rereading these exchanges after a lapse of some years, I think that their most striking characteristic is that neither academics nor (very advanced) students seemed to have any clear idea of what constituted science, let alone computer science. There are pleas that computing "comes from a very STRONG theoretical background", and that it "is based upon extending and developing this theoretical base, which is science" - perhaps a little better, but both views which Aristotle would have found congenial. We were supposed to have got beyond those at about the time of Galileo. We did it - or, rather, he and some mates did it - by daring to conduct experiments, to find out what really happened. Then they, even more daringly, suggested that the theory should go if the experiments didn't support it. It is this component which I find lacking in computing.

We also learn of science that "the term is a lot wider, as in 'political science'". So it may be, in common parlance - which is why the Oxford Dictionary supports this interpretation - but that certainly isn't its meaning in my discussion starter, where I suggested that "the material we cover is not regarded as respectable science". This lack of concern for the meanings of words is just one of the symptoms of our lack of intellectual rigour, and I argue this point elsewhere[5].

We are also urged that "the notion of an algorithm is the central theme of the subject". Excellent. The why don't we call the subject algorithms ? It certainly has only the most tenuous connection with computers - algorithms were alive and well for a long time before computers came along. But what are algorithms, anyway ? Is there a coherent body of thought about algorithms per se ? I don't know - but if there is perhaps it's related to logic, when I'd want to call it mathematics, or perhaps it's related to semantics, when I'd want it to be informatics. If there is no such body of thought, then algorithms is a collection of tricks for getting things done (engineering), and reduces to the "clever schemes" which I am concerned to avoid.

Enough. I could go on, and frequently do, but this last word is fast becoming a last chapter, and I am abusing my position as collator. We didn't really get anywhere jointly, though perhaps a few people learned something severally. We certainly didn't reach a state from which we can embark on the phase 2 I suggested in my introductory remarks - and that's a pity, because I think we still don't have a clear picture of what we, as a department, are supposed to be doing. I've tried to put forward ideas from time to time, both for the department as a whole[8] (not discernibly well received) and for my own stage 3 course[9], and will doubtless continue to do so. Meanwhile, we'll stagger along clutching at clever schemes to do with gee-whizz novelties like graphics and multimedia, which say little enough about what computing is, and a lot more about the paucity of our vision.

FINALE.

As this Working Note is all but on its way to the mighty presses of the Computer Science department, I am delighted to find these most apt quotations from a real authority[6] :

> *If control over computers is control over nature, then software is a form of engineering. It is an unusual form, however, in that while software is a practical subject, it has no direct connection with experimental science as that term is ordinarily understood.*
>
> *I believe that … computer science will come to be regarded as part and parcel of engineering and will be so recognised by the professional bodies.*

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4 : H. Barringer : "Up and down the temporal way", *Computer J.* **30**, 134 (1987); L. Lamport : "A simple approach to specifying concurrent systems", *Comm.ACM* **32**, 32 (1989)

5 : G.A. Creak : *Why do computists like gibberish ?*, unpublished Working Note AC68, soon.

6 : M.V. Wilkes : "Software and the programmer", *Comm.ACM* **35#5**, 23 (May, 1991).

7 : R.P. Clement : *The automatic generation of expert systems from examples*, M.Sc. Thesis, Auckland University Computer Science Department, 1987.

8 : G.A. Creak : *Computing - a course structure*, unpublished Working Note AC73, November 1989.

8 : G.A. Creak : *Operating systems course structure*, unpublished Working Note AC75, December 1989.