Session 3

"What Kind of Science is This?"

Heikki Pisto
Helsinki University of Technology
Control Engineering Laboratory

heikki.pisto@hut.fi

What is the purpose of science? Is it valuable in itself, or is it only supposed to serve other human interests? In his book The End of Science ***John Horgan*** *argues that age of scientific revolutions and breakthroughs is over, and that all there is left to do is to fill some gaps and that's it.*

3.1 Science, what is that?

Most of what can be called triumphant march of industrialised societies is basically built on two feet. One is the free market way of dividing and sharing resources, which has led to very profound specialisation between individuals. Market economy has in some form or another existed as long as homo sapiens itself. Nobody invented or discovered it, it seems quite natural, although there are good reasons to modify the rules and harness the actors if needed. The other, natural sciences, is also very old; it has its roots deep in the antiquity. There is much evidence, that the first advanced civilizations, like Babylonians and Egyptians, were clearly aware of benefits of what could be described as "applied sciences". From the golden age of Greeks there has survived numerous manuscripts, and many show clear interest to knowledge

purely because of itself, not only for economical or other benefits. This idea, so called basic research, has proven to be as crucial in scientific developments than the other half, applying. For example, celestial mechanics may seem to be useless endeavour at first, but it has always been one of the basic objects of curiosity of mankind. After one learns that earth is round rather than flat, vast possibilities immediately open.

The Greeks had much interest in philosophy, and they considered study of nature one branch of it, natural philosophy. They emphasised rationality, and tried to form laws about nature works. On the other hand, they did not consider testing of their theories with experiments too important, and some of their ideas are somewhat confusing, even silly, to modern person. The important idea, which emerged little by little during otherwise long and dark Middle Ages, was empiristic way of acquiring information about nature. In 13th century Grosseteste worked with optics, and concerned to verify theories by experiments. His student Bacon used mathematics to describe optical systems, and conducted systematic experiments with them. Later, the methods of Galilei, da Vinci and their successors of looking at the world through experiments became very powerful and popular. From those days on natural sciences have been increasingly related to mathematics. Observations needed interpretations, theories, to be useful, and mathematics was practically the only way to express them precisely. This symbiosis of mathematics and science is still in good health, but lately there have been some suspicions about this old paradigm of doing science.

3.2 Is the age of revolutions over?

Every now and then scientists have felt that there are no more things to discover. For a long time Newtons laws were good enough for everybody, mainly because they explained almost all of the common phenomena that occurred in everyday life. Electricity changed everything. This mysterious force raised new questions but also made possible to arrange new experiments, which revealed new phenomena, which in turn needed new theories. In early 20th century there were suddenly again plenty to do and explain, and it took some 50 years for particle physicists to clean up the mess. Towards the end of century there were again separate theories that were capable to explain basically all observations. The only problem is that these theories are not consistent with each other. Or is it a problem?

Today most of the questions concerning space, time and matter can be considered solved, at least for current practical purposes. The picture of physics

looks good, but it is The Reality? Hardly. And even if it was, the wholeness is way too broad to be mastered by any individual. Still there are people, who think it is worth trying. Some of the scientists have taken the quantum leap beyond experimentability, and continued making science in further dimensions. Although this means quite a change in the traditional virtue of science, it may not be wise to blame them for doing that. The ghost of Democritus is still lurking among physicists.

The other way to do progress seems to be to construct something from these already acquired building blocks of the Standard Model. Approaches are numerous. Economically the most lucrative branch of science is probably material sciences, where increase of knowledge has over the last 50 years caused another industrial revolution. The so called Moore's law, which says that device complexity on a chip doubles every 18 months, has held true for almost 40 years now, and probably will for at least 10 years. Stream of new applications will continue to distant future, and yet new markets will emerge. Unfortunately, as smaller details and scales are attained, the costs of investments in industry have risen as fast as the markets. The so-called Moore's second law states, that also cost of facilities increase on a semi-log scale. Modern semiconductor factory may easily cost billions and billions of euros in the future, which effectively keeps profits from rising exponentially. Biotechnology has also given big promises, but has not fully met them yet, despite huge amounts of investments. It is the same phenomenon that concerns basic research: For ever increasing use of resources there is inevitably diminishing amount of returns. It seems, that the progress is not slowing down because of lack of adept scientists. The potential scientist material is larger than ever. It is only that gigantic telescopes, particle colliders and fusion reactors seem to be the only way to go ever further to make any progress. Could it be, that scientists are running out of good ideas?

3.3 Is the Truth good, bad or ugly?

Science journalist John Horgan has taken to himself the burden of revealing the emperors new clothes. In his 1996 published book The End of Science he argues, that although there are vast amount of scientists, more than ever before, bustling around science, all they have left to do is to fill some gaps and figure out applications. He bases his argument on dozens of interviews he has made with some prominent scientists of late 20th century. They include philosophers, biologists, physicists, social scientists, neurologists, and people that he amusingly calls "chaoplexologists". By chaoplexity he refers

to complex systems and chaos research, which has over last decades changed names according to concurrent fashions. Through the interviews he creates quite ambiguous construction about modern science. Some of the scientists are looking for The Answer; somebody seems to already have found it. Some believe in the Big Bang, some swear by evolution. And all this is flavoured with Horgans sceptical and refined comments.

Horgan certainly hit a sore point. To make science is a profession, and "pure science", basic research, is mostly publicly funded. In private sector people working with technology and knowledge like to call it "product development", as contrary to "science" in public sector, even if they would be doing the same thing. Engineers in the private companies want to please the capitalists, scientists for one the taxpayers, the great public that is following their work. To this public it may sound quite confusing, if a notable science journalist declares, "it is all over, everybody go to your homes, there is nothing more to see". It may be a simple mans shot to make a handprint in the world, but what if ...?

The most common objection to Horgans argument has been "That's what they thought hundred years ago". Even though there are some famous quotes to support this, it is probably not true. Horgans answer is simply "No they didn't". For most of the sciences and scientists, this is the fact. In the end of 19th century science was by no means in a dead end, at least for a scientifically oriented mind. It is another thing, that for some spectators and appliers of technology, like Horgan hundred years later, it might have seemed that way. By Horgan this 100-years-argument means, that people want to say, "because science has advanced so rapidly over the past century or so, it can and will continue to do so, possibly forever". This rhetoric turns out to be a philosophical hypothesis, which sounds unconvincing, thus supporting Horgans point. Yet that is not too convincing either in its strictest form, as in the title of his book. If the truth is somewhere in between, what is the catch?

Some, if not most, of Horgans critic is pointed at something he calls "ironic science". His most important observation about modern science is, that either in lack of potential or because of pure curiosity about abstract, it is heading more and more to speculative mode, separate from verifiable physical experiments. Physical world is becoming engineering and is left for engineers, because for potential future Einsteins, the prospects are bad. For example there is superstring theory, which Horgan calls "naïve ironic science". Superstrings are mathematical constructions, that may make sense at certain level of comprehension, but is it really enough to form a world-view? String

theory can be described as speculative; it is not possible to do any experiments in its bonus dimensions, with energies unimaginable. Also some of its practitioners have almost religious relationship about their subject. When they see the truth, it is the truth, and should be treated as such, despite of the fact, that when none of its results are verifiable. They can in no way affect our lives.

It is known, that scientific revolutions result because of change of paradigm, way of seeing and doing science. This speculative mode may well be a new paradigm, at least if there really is nothing else to do. In that case, also the experimental method of science, which has hundreds of years been so successful, needs some new explaining. So far purpose of the theories has been to make explanations, and if possible, predictions about nature. Experiments have been necessary to evaluate usefulness of theories. If importance of experiments is diminishing, or it the experiments are changing too expensive to conduct, there is clearly a transformation going on between paradigms. To Horgan it means, that science is going into decline. Obviously situation in not such, that there is nothing to discover any more. But even though "Answers raise new questions", many of the questions are such by nature, that they cannot be critically answered with objective truth. Let's consider cosmology. Every layman can formulate questions, which are as impossible to answer as those of religion. Science has its limits because of its (present) method; there is nothing that can be done about it. And when we pass the method of science, it is the end of science? In Horgans opinion ironic science has its function, though. By handling unanswerable or unimportant questions, it reminds human beings, how little they know, and maybe sets their existence in perspective, if is doesn't happen to be there.

3.4 Cellular automata ...?

One common paradigm in doing science has been, that the truth in itself is somehow simple and beautiful. One of the more famous formulations of this is the so called "the Occam's Razor", after William of Occam (1300-1349), which basically recommends the simplest of all rational explanations to an observed phenomenon. This approach can be deceiving, for example in Horgans book it is gloomily quoted without reference, that "in biology Occam's Razor cuts your throat". Indeed, lots of interest has been spent since end of 19th century on dynamically complex behaviour of systems of several simple entities as opposed to studying properties of individual components. Many times the n-body problem has been considered as starting point for com-

plex systems research. After that there has been numerous important and fascinating examples of other such systems, for example strange attractors, fractals and cellular automata. All of them have been in turn very fashionable subjects, only to be replaced in a few years with something else. All these have the common treat that the beauty is not in the simplicity, but in their complexity. More specifically, what interests human mind is something between simple and complex, something that comes out of chaos and appears to be somehow more than the original ingredients. Philosophically speaking, for example in the case of cellular automata, all behaviour is essentially equal in system point of view. For external observer, in this case human being, there is in some cases more to see. With certain rules, some patterns expand infinitely, some survive indefinitely, and some repeat cycles, some die out. This is fascinating. So are fractals, too. But, what kind of practical results can be derived out of them? Stephen Wolfram says, that every kinds of results. In his book New Kind of Science he asserts, that basically the whole reality is working like cellular automata, and that knowledge about it can be acquired through simulations of other cellular automata. His hypothesis of computational equivalence suggests, that everything can be reduced to series of computations, which in turn can be carried out by very simple logic. This would mean, that everything could be simulated, and not just approximately, but precisely. This is another major deviation from current paradigms of science. Like superstring theory, it is a quantum leap into obscurity, and it seems quite difficult to work out the way back to normal, concrete world. And, before the connection is again formed with experimental reality, it is nothing more than metaphysics of ancient Greeks.

So what are we researching, when we study these so-called complex systems? Many scientists have been very optimistic about what can be forged out of them. Maladies, natural catastrophies, all kinds of messes can be cleaned up in the future which will make human life better. Yet all the progress so far has been discovering new intriguing dynamics in different kinds of systems, but little more. Characteristic for the research has been, that for every research subject there is real background somewhere in reality; complex systems researchers seem to be different from mathematicians, who do not care about nature as such. Only logic and consistency is relevant, abstract is a virtue. In set theory, it is not very professional to use apples and horses as members of sets. Then in complex side, people are more than eager to develop great stories about what is going on in their complex world, and relate new results straightforwardly with some other things in reality, even if there is no real connection. Then on the bottom line, horses are happy to eat apples, and it is much more probable for the research to get publicity

and funding. In the past it was work of the science journalists to make quantum mechanics sound interesting, now the researchers themselves do it. Is science becoming popular culture, and researchers becoming superstars? Of course Einstein and Hawking are superstars, although few have any idea, what is the content of their work. If there is any Philosopher's Stone to be found in chaoplexity field, it will give to its finder the most juicy stories of science history, and more fame that anyone before that. After all, some of the contemporary complex researchers have already had a taste of this, but everybody is not convinced yet.

3.5 Has the science become just a show?

Science has traditionally been prone to personality cults, even though great majority of all-important discoveries seem later quite inevitable. Planck's constant could well be somebody-elses-constant, Pauli's exclusion rule be Schulzennagel's rule. All this encourages generations after another to continue making science. It might be difficult for a young scientist to content oneself with only developing applications and giving lectures about existing knowledge. So many ambitious scientists couldn't have resisted the idea of inventing science rather than discovering it. If a theory great enough could be constructed so, that it would not contradict with any of the existing theories but instead would expand and incorporate them, then one could truly call that achievement regardless of whether it would be useful, or even experimentally provable at the moment. This approach has worked on several occasions before, most notably for special relativity. Basically this is also what Horgan calls ironic science. The first deliberate ironic comment was physicist Alan Sokals nonsense article in "a journal of cultural and political analysis" Social Text in 1996, just to test, if there really existed any more intellectual criticism among post-modern philosophers. The text passed the editors, and was not revealed as a hoax, until Sokal himself did it. At least in some people's opinion more serious occasion was in 2002, when the infamous Bogdanov brothers got caught for at least four gibberish papers, for which they also got their Ph.D:s in University of Bourgogne. The brothers had their own TV-show in France, and they were local celebrities. The alarm bells rang, and almost all of the people, who considered themselves scientists, wondered, what was happening to this their beloved mission for The Answer called science. Who can be so vain to do things like that? From outside point of view, though, there is no difference, if paper is written with hoax in mind or by studying something of little importance in itself.

All this might cause, that talented young people hesitate to choose scientific careers, and maybe prefer going for business or government, even after acquiring a scientific degree from university. Problem is not, Horgan argues, that there are no more questions to be answered. After all one can always wonder the meaning of life. If anything, there is shortage of good questions, which have always been essential. It is hard to imagine theories that would have even remotely same impact as evolution theory, general relativity or quantum mechanics. There are still many unanswered questions in biology and cosmology, for example. The nature of these questions is nonetheless such that every hypothesis is necessarily very difficult to verify, if not impossible. The beginning of life may remain unanswered forever, unless some life form resembling existing life really can be created artificially and repeatably from the elements. Also, the idea about the first moments of universe is so abstract, that one has take it with a grain of salt. It might be mathematically consistent in the scientist's head, but if it is true, that is a whole different thing. For an individual scientist, it might bring fame and welfare, even if the theory were false, as history can show. But from practical point of view, it is quite safe to remain dubious about such things. Scepticism has always been virtue in thinking, when it comes to matters, which have little tangible effects on life itself. Whatever that is.

3.6 Where to go?

> "It's like the jazz musician, who was asked, where jazz is going, and he said, 'If I knew, we would be there right now"'

Chaos research and complexity research is basically same thing under different names. Chaos refers to disorder, complexity to something elaborate and sophisticated, but still somehow ordered to human mind. One could say that weather is chaotic, you cannot predict that, let us say, for a year forward, although you can with big confidence assume that in Finland it is chilly. Some cellular automaton may be complex, but it is not really chaotic, because it is so discrete and computable. Both terms are quite ambiguous and mean different things to different persons.

Ways of attacking complexity are numerous. Purely theoretical, mathematical ones, like fractals and cellular automata, have produced little more than entertaining patterns. Some more practical approaches, like emulating nature by networks and agents, have produced some real applications, like Internet, where wholeness is so much more complicated than what the constructors

were planning in the beginning. It basically has a life of its own, and cannot be controlled by any single quarter. From the net point of view the users are not using the net as a traditional tool, but rather living in part the life of the net. If there were no voluntary diverse action in the net, it would be little more than an advanced telegraph. Internet is not designed to fulfil different sexual desires, but because of the human nature, the services emerged there. This for one encourages also other use of the net, also improving its usefulness. How could have this been possible to predict?

This something-from-nothing-aspect has characterised much of the research in the field. It is always good thing, when something interesting emerges. But, to make something really desired and useful effects, like future stock prizes or a wristwatch, to emerge from something trivially available resource, like computing capability or a ton or ore, appears to be daydreaming. But also it is impossible to tell, what is possible and what is not. Life itself should not be possible, because from human point of view, it is too complex to work. The complexity of complexity has encouraged certain researchers to make predictions about glorious future, starting from curing diseases, ending with world peace. Human being would move on from being part of the system to be the master of the system, knowing all relevant information, taking into account all side effects of its action on the system. Also many practical problems of an average person are complex in their nature, like guessing lottery numbers. Others are usually computationally equivalent of computing, if one has enough money for additional bottle of beer, or if one can afford to sleep ten minutes more in the morning. Such considerations will remain always the same, but in the best case in distant future, complex systems research could make the lottery meaningless, or maybe at least the stock exchange.

Up to the present the research of complexity and chaos has been more or less alchemy with computers. The hype has caused some people, eager to leave a handprint in the history, desperately seek for the Philosopher's Stone, which would convert complexity into simplicity. It should be evident, that this is not going to happen. But, after all, research of chemistry was based on alchemy. Alchemy was Isaac Newton's hobby, but not all alchemists were Isaac Newtons. And indeed something has emerged, if nothing else, then plenty of material for scientific Monty Python sketches.

Bibliography

1. Horgan, J.: *The End of Science* Broadway Books, 1997.