2 A WORLD OF BITS

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Prologue

We are living at a time of unprecedented change with technology advancing faster and producing more new opportunities and problems than ever before. Computers and telecommunication (IT) have not only created the means to generate even more information and do more in a shorter time, but they have also created the means of storing, accessing and transporting information on a scale that was inconceivable just 10 years ago. Every three years the sum total of mankind's information doubles, and creates more people who are data rich but information poor. Technology feeding on technology —a positive feedback and directed evolutionary process is the culprit.

In evolutionary terms, humankind is both in a cul-de-sac and static. In short, we are going nowhere! While our wet ware (the brain between our ears) quadrupled in physical capacity over a mere 100,000 years or so, the last 15,000 years has seen no significant change. Moreover in the next 15,000 years it will not change or evolve further, for it looks to have reached the end of the road. So if we as a species are to keep up with a world of technology, that is increasingly changing faster than we can now accommodate, we have only one course of action. We have to embrace technology to cope with the changes introduced and provided by technology.

Long Term Perspective

We only have to look back less than 2,000 years to see much of mankind living in tribal communities of 200 or less. In an entire lifetime people might only meet 1,000 human beings. For this life as the hunter, gatherer or farmer, we were well equipped. All of the tribes' knowledge and indeed almost all of mankind's knowledge could be contained in one human brain and passed on from father to son, mother to daughter. Libraries did exist, but they were for a select few, the information elite, the ruling class. For most, all the information they ever required was within the tribe, within one or two heads. In a

period of less than 200 years, the transition of much of the world from farming and a rural existence to an industrial era was complete. During this time, the ability to physically transport large amounts of goods and people across the planet emerged and created demand for good telecommunication. It is interesting to reflect that our supremacy at waging war was the primary motive for the development of much of our industry that led directly to today's revolution in IT. But perhaps more impressively, we have created yet another era for mankind in much less than 100 years. When De Forest invented the thermionic valve in 1915, he could never have guessed the revolution that he was about to start. The next major step forward was the invention of the transistor in 1946 by Bardene and Shockley, to be followed by the laser in 1960, the integrated circuit in 1969, and optical fiber in 1972.

In just 25 years, we have seen the world become dominated by integrated circuits (chips) and optical fiber, with IT in abundance we have created more information, achieved more, and understood more than all previous generations. This pace of change will not only continue, it will accelerate—it is exponential! Every year sees optical fiber able to transport twice as much traffic, memory chips able to store twice as many bytes, and processing power of computers doubling. Many people consider English to be the primary language of the planet and, of course, human language to be the most sophisticated and dominant form of communication. Well, they're wrong! The most prolific form of communication is now binary, it is between machines and they now have more conversations in a working day than the rest of humankind has had during its entire existence going back to Eve. We can now wear more computing power (a wristwatch) than the commercial computer the size of a washing machine had 30 years ago. The desktop computer can be expected to be 1,000 times more powerful in 10 years time, 1,000,000 times more powerful in 20 years, and possibly 1,000,000,000 times more powerful in 30 years. Sometime around 2015, the supercomputer as powerful as a human from a processing of information and storage point of view will be produced. About 10 years after that it will be on our desks and five years after that, it will be wearing us. If our species is to maintain a role on this planet and, in many respects, stay in control, we not only have to understand the technology but we have to use it to advance our own limited brain capacity. It is not possible to sit still, opt out, or just plain ignore these changes for they are inexorable and they will promote even more change. In short, you can opt out but you can't escape.

User Unfriendly

There is absolutely no doubt about it, most IT interfaces are user unfriendly. They seem to have been designed by people who feel the human race should be converted into computer scientists. This is absolutely the wrong approach. The average human being has great difficulty driving a VHS tape recorder let alone a personal computer. Unless we see a move toward the humanization of interfaces (making devices extremely user friendly and easy to use), a society that is divided by its abilities and inabilities to interface with machines will be born. This would be both divisive and disastrous as a society of the IT have and have nots. It would be full of tension and sub-optimal from a productivity and survival point of view. It is absolutely vital that technology is bent into people and people are not bent into the technology.

Today we use mouse, keyboard, and screen. This can only be viewed as archaic and something of a past era that should not be allowed to survive much longer. Fortunately the technology itself is now reaching a point where voice control and command and even limited conversations are possible between humans and machines. This Star Trek vision is the first step in a series that will take us to a symbiotic relationship between carbon (us!) and silicon (chips). In a way, it is also the first example of a first direct linking of the nervous systems of two different life forms. The next extension will be that of our sense of touch as fingertips and other sensitive areas are coupled directly into the technology. In the meantime, we have to make do with sight and sound, with head mounted screens, cameras, microphones, and earphones. But even with this limited duality, we can achieve tremendous changes with the technology as we increase the input/output rate of information between human and machine.

Real Society

While technology changes our world irrevocably, there are many features of it that remain and will remain for decades to come. But it is worth noting that we live in a society where the governing mechanism involves people sitting two sword's lengths apart acting a little like demented school children and debating on issues eyeball to eyeball. The decision making processes of such systems are orders of magnitude slower than their counterparts in the virtual (electronic) world. Institutions such as banks, the City of London, other financial organizations, are being touched by technology in ways that are changing them and impacting on our society. To be blunt, the vast majority of bank branches are no longer required and it is conceivable to run the entire operation from one location or even no location at all! The same is true of the City of London as these operations deal primarily with information and not money, for gold is now just an abstract concept, as is the pound and other currencies. It is important to have the people and technology in one location in the manufacturing and production of physical entities. From the production of cars to the baking of bread, we have to bring people to one place to work and interact with raw material—atoms.

In reality, without information technology, we could no more bake enough bread than we could catch enough rabbits to feed the population and, if information technology were to fail, then the vast majority of the population would starve. The baker no longer exists, he is a program in an artificial intelligence system that controls and manages the manufacture of bread to a precision and quality that is way beyond that of any human baker. The same is true of steel production and many other commodities.

The Virtual World

On a Saturday morning, I can struggle into Ipswich, park my car, walk across town, buy some software at a very high price and return home. Alternatively, I can go onto the net, access the software I require directly from the supplier in California, pull it down from the network, and pay for it without even leaving my machine. The advantage is not only in the time and inconvenience saved but also in the much lower cost of the virtual product that no longer requires a wholesaler, a distributor, and retail outlet. The same

is true for the library or bookstall and potentially for all forms of "soft products." Such thoughts alarm many people when they ought to make them feel quite relaxed. For this virtual world is not an instead of technology, but an as well as technology. It opens up a new way of doing things and therefore new forms of trading and enterprise. Shopping, entertainment, education, and training, from your desktop at home, at work, or wherever you happen to be are now very real options. They are also opportunities for a new industry creating and selling to a new and dynamic market.

Not Quite in Time

The difference in the old world and the new is exemplified by the typing pool. Only a decade ago, large organizations had a central resource called the typing pool staffed by young women whose sole purpose was to take the hand-written or spoken text from paper or tape and transcribe it onto the typed page. The process could take several days depending on how busy they were or how long the queue was. The very thought is inconceivable today. Who would operate in such a way? Things are now turned around in a matter of minutes, not a matter of days. Modern companies operate with telephone, fax, e-mail, video conferencing; they have very low flat structures (if any) with people empowered to make local decisions and get on with the job fast! Any form of delay is just inviting the competition to take away your business and your markets. Fortunately, the same is true in education and training. Any school, college, university, or training establishment that sits back and continues to use the old chalk and talk methods of Aristotle and beyond are destined for extinction. We have to move forward with the technology if we are going to keep up with a world that changes ever faster.

Just in Time

Thirty years ago, the vast majority of children came from homes with very few books and went to school to access information, knowledge, and education. Today, unfortunately, it is often the case that the reverse is true. For many children with top-end computers at home, access to CDs and the network, they see school as having very little to offer.

For the most part, our society is split at about the age of 29, with those above computer illiterate, and below, computer literate. So it is not unusual to find a class dominated by a teacher who is IT illiterate, technology incompetent, and therefore feels threatened by a class full of ability. This problem is further compounded by the life style of children, which is now partly governed by the games environment of instant gratification, learning intuitively, and a crash and burn culture. They feel no inhibition in discovering by doing and coming to grief in full public gaze. The cultural background of their elders, however, is quite the reverse. The question is now how to bridge that gap, or even if we should try, and what the advantages and disadvantages might be.

Some Examples

Traditionally, a dentist, a surgeon, the maintenance engineer, a scientist would educate and train a small number of people through direct tutoring. This is an echo of the Greek tradition, and necessary for a number of reasons. First of all, for a surgeon or dentist operating in a small orifice, only one or two people were able to crowd the area and see first hand. Second, as a species, there is a finite limit to the number of people with whom we can simultaneously communicate and this is usually quite small. But, with telepresence technology it is possible for a one to many or one to one experience to be realized far more efficiently and on a massive scale. The surrogate head is just one development where microminiature television cameras above the eyes, and microphones above the ears, collect information in real space and time. This can then be transmitted and displayed on a screen, or a VR headset, to one or more people in any location on the planet. So a surgeon can perform an operation with a thousand protégées standing inside his or her head looking out. Conversely, when a protégée performs the operation for the first time, that surgeon can stand inside and advise in the closest possible sense.

Within the next 10 or 15 years, the addition of touch to such a system will make the human experience almost complete. This might sound like far-fetched technology, but it exists in the laboratory today. It has been used for real operations on humans over standard dial-up ISDN circuits. This technology is applicable to a wide range of disciplines and has the potential to completely changes the training paradigm, which can then become just in time.

In a simpler variation, the nurse practitioner can now visit a patient with a laptop computer, GSM phone, and video camera. On arrival, an inspection of the patient's problem can result in still images being transmitted back to a general practitioner with on-line consultation diagnosis and treatment details being discussed and realized.

On a more mundane level, there are now 24,000 CDs available for use with personal computers. These contain everything from the classic books through the whole body of interactive encyclopedias, scientific experiments, and university degree courses. If a book or a video is an echo of the life persona of a human being who may be a great teacher, then the interactive CD, constructed by that teacher over a lifetime with interaction with classes asking questions and discussing in-depth, becomes something close to adverting death itself. The teaching of difficult topics in science and engineering can now be enhanced significantly through computer animation and visual representation. There is probably no worse-taught subject than mathematics. It terrifies most of the population and just leaves them mystified. This is principally because people who teach it are unable to get across the abstract concepts. In this regard, the CD and interactive multimedia is far superior to a human for large tranches of the process.

Half Life Education

Many engineering and scientific degrees in fast moving areas of technology now have a half life of five to seven years or less. Moreover, the time when a single discipline primary degree was sufficient for a lifetime of work has long gone and it is not unusual

to find electrical engineers, for example, now concerned with biology and genetic engineering. So it seems time to create a new form of degree that is much lower, much flatter and generic, able to equip people for a world that will change inexorably over their working lifetime. On top of this is required a series of higher degrees that can be rapidly acquired as technology and work changes. But as business life and industry also accelerates and demand increases, then so does the pressure to hang on to that scarce trained resource that is key to the success of the very enterprise itself.

It is partly in response to this conundrum that my company created a series of internal degree courses just five years ago. The organization and running of these courses was under the auspices of several conventional universities banded together to create the desired profile and course content. This in itself is a dynamic entity as each year the course material changes and adapts to the business of the company. Everyone wins: the students who becomes increasingly empowered and capable, the company that has a work force it requires, and the university with access to key people and activities in industry.

In the first instance, the courses were run in a conventional manner with students and teacher in a lecture theater gathered together for a few hours a week, followed by tutorials and assignments. More recently, a new format has begun to unfurl with lecturers from North America and other developed regions being teleported into the lecture theatre by ISDN dial-up lines. They appear on a three meter square screen, to give their lectures eye-to-eye with suitably mounted cameras. Only two years ago, such a lecture cost £60 for the communication connection; today it is only £40, much less than the hotel charges for a real lecture in a real hotel. There are those who would argue that this is not a real experience and is not as good as the real thing and, while this may be true, the choice is rather more stark. Either you have the electronic experience, or none at all! On that basis the students would sooner have world experts in front of them electronically than never being in their presence at all.

More recently, the next step has been taken! Teleporting the event to the desk of the individual student so that they no longer have to break away from work 100% and they don't have to crowd into a lecture theater. They can now attend courses or tutorials and interact with each other directly on the screen. The outcome of this experiment has yet to be fully quantified, but at the time of writing all that can be said is that it works!

The Critics

There are very few human beings who look forward to or enjoy change on a large scale. This is certainly true of the education establishment and many who are involved in a more indirect way. The primary direction of criticism always seems to be, "that's not the way they did it in my day!" I suppose if we went back to the time of Archimedes and Aristotle, people were saying much the same thing about their methods of teaching too. The reality is that just 50 years ago in a British university, the lecturing and teaching scene was totally different. Today you can still see the benches at the front of the lecture theater where experiments on a grand scale would be conducted in front of an enthralled class. This was real reality, real teaching in a manner that has long been lost. Why? Because education has continually been squeezed and changed and now we

have small universities with pitifully small departments trying to do far too much in too short a time. Students are being asked to subsume more and more information and experience in a shorter time, which ultimately becomes an impossibility and the amount of staff/student time has declined drastically. By and large, most university staff members that are active have far too many research students and far too many classes to teach. An even worse difficulty is that most departments are sub-critical in the number of people that they have with the right abilities. No doubt, all of the abilities required to create a suitably well qualified and able department, with all the right skills, are available across a country. The problem is that they are seldom, if ever, available in one location—a university.

The Virtual University, an ethereal space in the information world, overcomes this barrier and allows groups of people with the right interests and skills to come together to work and be proactive. But it does mean a different mind set, and it means a different way of doing things. Unfortunately for the traditionalists, there is no other solution. There are no conventional human-based techniques to allow us to achieve the objectives that we need to achieve as the technology changes and drives our society. It is, therefore, imperative that we embrace the technology and experiment to find out what works and what doesn't.

Interestingly, in programs with children, it has become abundantly clear that the number one impediment is not the raw material—young people—but the older people who are trying to impart their experience and knowledge. It is perhaps not surprising to find that youngsters view university, college, and school as boring and uninteresting places where the teaching methods have not changed since the time of Aristotle. These young people happen to come from a world of instant gratification, of IT and rapid access and experience, of new and dynamic skills learned in new ways. The opportunity and challenge are both vast and exciting, for it is now possible to illustrate and explain immensely complex systems and situations with the technology of visualization and, soon, with virtual reality. Unlike Crick and Watson, students should not have to construct a model of DNA using cardboard and coat hangers, but have access to the mathematical representation of a visual form that is both exciting and edifying.

The Future

My father had a working life of 100,000 hours and I can now do his work in 10,000 hours, my son will be able to do it in 1,000 hours, and so on. The work I did as a young engineer in my twenties that took a whole morning is now done in less than 15 seconds by the power of computing and control. This level of progress is assured for at least another decade as we can see all of the techniques and all of the technologies on the laboratory bench today. It is likely that it will continue for at least another two decades and probably three, but after that there will be change as we reach the ultimate limit of using subatomic particles as transistors (switching elements). There is no doubt that our history has shown that our innate curiosity, creativity, and inventiveness will generate even more technology. There is now, however, a new proviso and that is, if we can keep up with the technology ourselves. We have to keep ahead, stay educated and trained, and somehow understand things that currently defy our rather limited wetware.

About the Author

Peter Cochrane joined BT Laboratories in 1973 and has worked on a wide range of technologies and systems. In 1993, he was appointed as the Head of Research. A graduate of Trent Polytechnic (now Nottingham Trent University) and Essex University, he is also a visiting professor to UCL, Essex, and Kent Universities and a Member of the New York Academy of Sciences. He has published and lectured widely on technology and the implications of IT.

Dr. Cochrane led a team that received the Queen's Award for Innovation & Export in 1990; the Martlesham Medal for contributions to fibre optic technology in 1994; the IEEElectronics Division Premium in 1986; Computing and control Premium in 1994 and the IERE Benefactors Prize in 1994; the James Clerk Maxwell Memorial Medal in 1995; IBTE Best Paper Prize and Honorary Doctorates from Essex and Stafford Universities in 1996. E-mail: pcochrane@bt-sys.bt.co.uk