Man and machine: a miraculous partnership

JACQUELINE LAM KAM-MEI

An account of the interaction between Stephen Hawking and his computer-driven voice synthesizer

IT WAS over 30 degrees centigrade on the 16th of June 2006, but hundreds of people from various backgrounds embraced the heat and patiently queued to enter the S. H. Ho Sports Hall at the Hong Kong University of Science and Technology (HKUST). Many had been waiting since early morning, because Professor Stephen Hawking – perhaps the best known and most influential living scientist – would be giving a lecture ('The origin of the universe') for the newly established Institute for Advanced Study. The IAS is dedicated to 'the advancement of knowledge to meet the great challenges of the 21st century', and will 'bring together the world's most brilliant minds to drive cutting-edge discovery and scholarship for the betterment of mankind' (IAS, 2006). The inaugural event was announced a month prior to the lecture and – despite its being broadcast live on both the TVB News Channel and Cable TV Live, as well as transmitted via an intranet relay to the seven other tertiary institutions in Hong Kong – the response for tickets was overwhelming.

Introduction

At the time I was working in HKUST, in the Language Centre, as a teacher of English. Although not a scientist, I was intrigued when I received an e-circular from the University's Development and Public Affairs Office inviting staff members who wished to attend to register for the event. One sentence in the text particularly caught my attention: 'Please be advised that, as Prof Hawking communicates mainly through a computer synthesizer, there could be considerable time lapse during his lecture.' A computer synthesizer? A considerable time lapse? What was the connection between the two?

Stephen Hawking suffers from amyotrophic lateral sclerosis (ALS), and not so long ago it would have been impossible for someone suffering from ALS to communicate one to one and face to face, leave alone give a lecture on a stage to over 2,000 academics, politicians, professionals of various kinds, students, members of the public, and, importantly, other physically challenged individuals.

I had the good fortune to secure a seat in the hall, and found myself sitting next to a young computer professional, a graduate of the City University of Hong Kong who was interested in cosmology and had read Hawking's best-selling *A Brief History of Time*. He told me that it was not difficult to understand the book, and that he found Hawking's theories fascinating. As we chatted about black holes and baby universes, Hawking appeared on the stage in his wheel chair. The overhead lights in the sports hall dimmed and lights in the backdrop of the stage began to glow, becoming a starscape onto

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which his face was projected beside the vast title of his presentation: 'The Origin of the Universe.'

Looking at the vast sudden close-up of the professor's face, one could hardly see any movement save the blinking of his eyes. But a clear loud voice said 'Hello, can you hear me?', and the lecture began.

Genius and a deadening disease

ALS is the disease that claimed the life of the American baseball star Lou Gehrig, after whom it is also known, more informally, as Lou Gehrig's Disease. It is a rare progressive and usually fatal disease that attacks the neurons (nerve cells) responsible for controlling one's voluntary muscles. Without those muscles, we cannot move, speak, breathe, or even swallow. ALS progressively destroys the nerve cells in both the brain and the spinal chord, causing muscle weakness, paralysis, and impaired breathing, speaking, and swallowing. However, in most cases intellectual capacity remains intact, and this is particulary true in Stephen Hawking's case (cf. NIH, 2003). It also kills more than a hundred thousand people a year, worldwide.

Hawking was diagnosed as having an incurable disease shortly after he reached twenty-one, while undertaking cosmological research at the University of Cambridge. Since he did not know how rapidly the disease would develop, his research suffered. It was only the prospect of Jane Wilde becoming his wife that gave him the incentive to finish his doctorate. As he has put it (Hawking, 2007): 'That engagement changed my life. It gave me something to live for. But it also meant that I had to get a job if we were to get married.'

After he obtained his doctorate in 1966, he applied for and became a Research Fellow, and later a Professional Fellow, at Gonville and Caius College in Cambridge. In 1973, he left the Institute of Astronomy and joined the Department of Applied Mathematics and Theoretical Physics, where he became Professor of Gravitational Physics in 1977. Since 1979, he has held the post of Lucasian Professor of Mathematics. This venerable chair was founded in 1633 with money left by Reverend Henry Lucas, a member of Parliament for the University, and was first occupied by Isaac Barrow, and in 1669 by Isaac Newton.

Hawking made his reputation by investigating one particular set of problems: singularity and the event horizons around black holes, and probably also at the beginning of time. His first major work was co-published in 1968–70 with Roger Penrose and George Ellis. Basing their work on Einstein's General Theory of Relativity, they demonstrated the 'singularity theorem' – that every solution to the equations of general relativity guarantees the existence in the past of a singular boundary for space and time. In 1974, working on his own, Hawking formulated another significant concept, now known as Hawking radiation, which is associated with the quantum evaporation of exploding black holes (Schaefar, 1994).

His best-known work, *A Brief History of Time* (1988) discusses the concept of 'universe as a wave function'. With Professor James Hartle of the University of California at Santa Barbara he used an elegant vacuum fluctuation model to provide a mathematical rationalization for the universe popping into existence at the beginning of time. Although speculative, this concept has led scientists to a deeper understanding of the event usually thought of as 'Creation'.

Unfortunately, as Hawking's scientific achievements accelerated his health problems intensified, and in 1985, after a tracheotomy, an incision made in the trachea to relieve an obstruction to breathing, he was no longer able to speak. Before this happened, and despite slurred speech, he could be understood by people who knew him well, dictate scientific papers to a secretary, and give seminars through an interpreter. Now, however, he could only communicate by spelling out words letter by letter: by raising his eyebrows when someone pointed to the right letter on a spelling card. Making conversation was tediously difficult and writing a scientific paper close to impossible. In such a situation, Hawking's cutting-edge ideas would not have been passed on, and, had he lived a century ago, many of his thoughts on the universe would never have been recorded.

Technological angels

The use of special 'assistive' technology (cf. William, 2001), including a speech synthesizer and computer software, has made all the difference. Aware that Hawking's means of communication was slow, exhausting, and frustrating, Walt Woltosz, a computer expert in California, in the early 1980s gave him a copy of Equalizer, a program he had written that can predict and complete words in sentences,

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speeding up the ability to communicate of people with such disabilities as ALS. Equalizer can convert text to speech via an integrated-synthesizer program on any PC using Windows 95 and a processor running at a minimum of 133 MHz. As a result, he need only press a switch with fingers of his right hand (which retains limited mobility) to select words from menus on his screen.

Such software is both a communications tool and an environmental control, allowing him to turn appliances on and off, to select a CD, or to control almost any device with an on/off switch. This interface, used on Windows 98, is called EZ ('Ee-Zee') Keys, a product of Word Plus, which he finds 'absolutely essential', because he can use it to produce and edit presentations, papers, and books. The program's word-prediction database holds up to 5,000 words and can save thousands of set phrases that can be quickly retrieved and vocalized:

> I can save what I write to disk. I write papers using a formatting program called TEX. I can write equations in words, and the program translates them into symbols, and prints them out on paper in the appropriate type.
>
> (Hawking, 2007)

With this assistive technology he was able to revise the draft of *A Brief History of Time* (1988), whose remarkable success could hardly have been predicted. By April 1993, there had been 40 hardback impressions in the US and 39 hardback impressions in the UK. The *Guinness Book of Records* (1998) records that, by May 1995, *Brief History* had been in *The Sunday Times* best-sellers list for 237 weeks, exceeding the previous record by 58 weeks, and notes that the paperback (April 1995) reached number one on the bestseller list in three days.

EZ Keys could at first only be used on a desktop PC, which was slow and not convenient for the highly mobile life that Hawking was leading. To improve things, David Mason, of Cambridge Adaptive Communication, fixed a small portable computer and a speech synthesizer to Hawking's wheelchair. As a result, he can currently manage up to 15 words a minute, and either speak what he has written or save it to disk and call it up later to read or to print, sentence by sentence. By using this system, Hawking has written some dozens of scientific papers and a book.

The speech synthesizer enables him to give both scientific and popular talks. Despite its giving him an accent variously described as Scandinavian, American, or Scottish, Hawking credits the remarkable outcome to the synthesizer: 'I think that is in a large part due to the

Keeping up with technology

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Recent developments in the assistive technology used by Stephen Hawking

Pentium chip. In November 2003 the company Intel gave Hawking a new custom-made mobile computer system. With inbuilt wireless, the system is powered by a Centrino Pentium M 1.5GHz chip, and allows access to the internet throughout his home and office. When he travels to non-wireless areas, he can still get internet assess through a mobile account that Intel manages for him, via a Nokia laptop card phone.

Windows XP. Hawking's new computer runs on Windows XP. This was previously impossible because his favourite speech software, Equalizer, (see opposite), was created some years ago, and could only run on DOS. The upgrading came into effect when Intel funded the conversion of the software to XP, and got Words-Plus to rewrite Equalizer for the upgraded operating system.

PowerPad batteries. Hawking's laptop is powered by a set of slim PowerPad batteries on his chair. It can also be powered directly from his wheelchair motor battery whenever necessary, to suit his active lifestyle.

Telephoning. By sending digital commands from his computer, Hawking can instruct his system to dial a number, to answer the phone, or to hang up. He can use either his laptop mobile card phone or connect his chair computer directly to a telephone socket.

Remote control. A radio-controlled device enables him to open doors and operate lights throughout his home, and with a universally programmable infrared remote control attached to his computer he can operate electronic items in his home, including TVs, video recorders, music centres, and doors in his workplace. In the newly opened Centre for Mathematical Sciences, he can move about the building unassisted.

<Information is based on Stephen Hawking's website at http://www.hawking.org.uk>

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Some questions and answers: Stephen Hawking in Hong Kong, June 2006

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From the HKUST newsletter, *Genesis*, 17:3, June 2006

Q1 Do you have any ambitions to fulfil?
I still want to know more about what happens inside black holes, how the universe began and more immediately if the human race can survive the next 100 years. I would also like to understand women.

Q2 What is your relationship with your children? Do you get to spend a lot of time with them?
I have three very attractive children, Robert, Lucy and Tim, whom I'm very close to, even though they are all now grown up and independent. My daughter Lucy, is with me on this trip. She and I are writing a book on science for children. It will be a bit like Harry Potter and the universe, but science, not magic. It will be aimed at the same age range.

Q3 Is there a role for God in this universe?
The French scientist, La Place, explained to Napoleon how the laws of science would determine the evolution of the universe. 'But where does God fit into this picture?' asked Napoleon. 'I have not needed that hypothesis,' was the reply.

Q4 How important is scientific research as the driver of economic growth?
Research on fundamental science has to be directed by scientific considerations, not economic ones. But progress in fundamental science often brings great economic benefits. For example, the work of my predecessor, Paul Dirac at Cambridge, made possible the development of the transistor, on which all of the modern electronic and computer industries are based. And the discovery of the structure of DNA by another Cambridge man, Francis Crick, is the basis of the biotech industry.

Q5 When do you think human beings could really reside on another planet? Do you think human beings need to do so?
In 20 years, we could have a permanent base on the moon, and in 40 years, a base on Mars. But both the moon and Mars are small, and either have no atmosphere, or not enough. We won't find anywhere as nice as Earth, unless we go to another star system. It is important for the human race to spread out into space for the survival of the species. Life on earth is at an ever-increasing risk of being wiped out by a disaster, such as sudden global warming, nuclear war, a genetically engineered virus, or other dangers we haven't yet thought of. But if we can avoid killing ourselves for the next hundred years, we should have settlements that can continue without support from Earth.

Q6 Is the universe a black hole?
At first sight, the big bang looks rather like the time reverse of a collapse to a black hole. However, there is an important difference. In the big bang, the universe starts out smooth and uniform, with only tiny fluctuations. On the other hand, the collapse to a black hole will be highly irregular and non-uniform. This difference can be explained by the no-boundary proposal. The history of the universe in imaginary time will be a closed, almost smooth, surface. However, there will be small fluctuations because of the uncertainty principle. On continuing back to real time, these fluctuations grow with time. They are small in the early universe, and large in gravitational collapse. The early universe is not the time reverse of black hole formation.

Q7 Could gravity distort light?
Gravity does indeed distort light. It was one of the predictions made by Einstein in 1915, when he proposed the general theory of relativity. The gravity of the Sun curves the space near it, and deflects light passing through it. This was verified by observations during the eclipse of 1919. Light from a distant star passing near the Sun was bent through a small angle, causing a slight shift in the apparent position of the star, relative to other stars.

Q8 We have many constants in this universe, e.g.: speed of light, boiling point of water, gravity. Where do these constants come? Why are they here? What will happen if the values of these constants are changed?
The constants of nature are determined by the parameters of the standard model. According to M theory, these are given by the geometry of the six dimensions of space that are curled up small. There is a whole landscape of possible values for these parameters, but most of them give universes that are not suitable for the development of life. Only in a few universes will intelligent life appear, and ask why the constants of nature have the values they do.

quality of the speech synthesiser, which is made by Speech Plus. One's voice is very important. If you have a slurred voice, people are likely to treat you as mentally deficient: Does he take sugar? This synthesiser is by far the best I have heard, because it varies the into-

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nation, and doesn't speak like a Dalek' (Hawking, 2007, referring to a robot-like enemy in BBC TV's science-fiction serial *Doctor Who*).

A miraculous partnership

Professor Paul Chu, President of HKUST, opened the lecture by saying, 'Professor Hawking, you represent a miracle of the human mind and the triumph of the human spirit.' As Chu's voice grew softer, the voice of Hawking's synthesizer came out loud and clear, and he began his lecture. There were inevitably time delays in using the synthesizer, but the flow of ideas was unaffected.

Hawking began by talking about the development of cosmology, ranging from the ideas of early thinkers such as St Augustine of Hippo to such pioneers of the modern era as Einstein. He contrasted various ideas on man's beginnings with the findings of science, noting that Bishop James Usher in the seventeenth century had, with remarkable precision, calculated the date of human creation as October 27, 4004 BC. By contrast, classical Greek philosophers thought that the universe had existed forever, and it was not until Einstein had developed his general theory of relativity (in 1915) that scientists concluded that the universe actually began at a particular 'time'.

In his twenties, Hawking brought new mathematical techniques to bear on the concept of black holes, allowing him to theorize in a new way on the beginning of the universe. He stressed that quantum theory is important in understanding the moment of the big bang, when the universe was only one-billion-trillion-trillionth of a centimeter in size. The essence of this idea is that:

> the big bang was not the abrupt switching on of time at some singular first moment, but the emergence of time from space in an ultrarapid but nevertheless continuous manner. On a human time scale, the big bang was very much a sudden, explosive origin of space, time, and matter. But look very, very closely at that first tiny fraction of a second and you find that there was no precise and sudden beginning at all. So here we have a theory of the origin of the universe that seems to say two contradictory things; first, time did not always exist; second, there was no first moment of time. Such are the oddities of quantum physics. (Davies, 1995)

There are, however, still many unanswered questions. He would for example like to know what happens inside black holes, how the universe began, and how the human race will get through the next hundred years.

The lecture ended with a rousing ovation, after which he responded to questions posed by both the university community and members of the public. A group of disabled young people wondered how he manages to maintain such a positive outlook on life, given the extent of his amyotrophic lateral sclerosis, to which he replied, 'Even if one is physically challenged, there is a lot one can achieve, as I have shown. You can't afford to be disabled in spirit as well as physically, or people won't have time for you.'

Asked why he has an American accent, he

Books and videos by Stephen Hawking

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Books

1973 with G.F.R. Ellis, P.V. Landshoff, & D. R. Nelson *The Large Scale Structure of Space-Time: Cambridge Monographs on Mathematical Physics*. Cambridge, UK: Cambridge University Press.
1988 *A brief history of time: From the big bang to black holes*. New York : Bantam Books.
1992 *A brief history of time: A reader's companion.* New York : Bantam Books.
1996 with Roger Penrose *The Nature of Space and Time.* Princeton, N.J.: Princeton University Press.
1997 *Stephen Hawking's Universe: The cosmos explained by David Filkin and Stephen W. Hawking.* London: BBC Books.
2001 *The Universe in a nutshell.* London: Bantam Books.
2002 *On the shoulders of giants*: *The great works of physics and astronomy.* Philadelphia: Running Press.
2005 *God created the integers: The mathematical breakthroughs that changed history.* Philadelphia: Running Press,
2005 (with Leonard Mlodinow) *A briefer history of time*. New York: Bantam Books.

Videos

1991 *The creation of the universe*. Irvington, N.Y.: Voyager.
1993 (with Isobel Hawking, Janet Humphrey, and Mary Hawking) *A brief history of time.* Hollywood, California: Paramount Home Video.
1997 *Stephen Hawking's Universe: Vol. 1 The big bang*. Hollywood, California: Paramount Home Video.
1997 *Stephen Hawking's Universe: Vol. 2 On the dark side*. Hollywood, California: Paramount Home Video.

A fuller list of Hawking's publications can be found at <www.hawking.org.uk>

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half-jokingly replied, 'The voice that I use is a very old hardware speech synthesizer made in 1986. I keep it, because I have not heard a voice I like better, and because by now I have identified with it. But the hardware is large and fragile, and uses components that are no longer made. Thus I have been trying to get a software version. But that seems very difficult. One version had a French accent. I said if I used it, my wife would divorce me.'

An admirable spirit

At a press conference some days before the lecture, Hawking was asked to comment on an incident relating to Bun Tsai, a local Hong Kong man, who appealed publicly for legalized euthanasia after being paralysed in an accident. The issue sparked a concerned debate in the city. 'I think he should have the right to end his life, if he wants,' Hawking said, 'But I think it would be a great mistake. However bad life may seem, there is always something you can do, and succeed at.' After the lecture, Bun Tsai, in a wheelchair, told the media that Hawking's life story made him realize he is not 'completely useless'; indeed, it encouraged him to write a memoir, to encourage other people in similar situations (cf. Cray, 2006).

In addition to its effect on the physically challenged, Hawking's visit appears to have enhanced scientific awareness among the young. As a role model he demonstrated how mind and spirit can combine to overcome difficulties and achieve success. One of the great minds of our time, he has made ground-breaking cosmological discoveries. He is also one of the world's most recognised, and recognisable, physically challenged people. Although he has not lost his ability to think, he has lost the ability to speak. If this manifest genius had not been equipped with the right kind of assistive technology, the world would have lost his ongoing contribution to science. Now, he works to unlock the secrets of the universe, with EZ Keys and a computerized synthesizer, and the world can hear him, loud and clear.

As we walked from the sports hall, my neighbour and I both expressed our admiration. It is not that the *content* of the talk was unimportant, but it was the courage and determination that Hawking showed that touched our hearts. I mentioned to him that I was thinking of writing about Hawking for a language journal. The next morning, when I turned on my computer I found the first of several emails from P with information on the computerized voice synthesizer that Stephen Hawking is using.

In writing this piece, I have been constantly confirming my memory and data by revisiting the HKUST website. The process brought me back to that beautifully located university, in Clear Water Bay, where I worked for close on fourteen years. The university seeks to become the MIT of Asia, and has put much effort into maintaining the role of international research university. In this university I used a range of scientific and technological aids to help students learn better, in both English and other languages, and to express their ideas more clearly. Having been trained as an applied linguist in Arts subjects I am not highly technical, but my faith and interest in technology grew along with the university: scientific and technological advancement, well handled, will benefit all of us, and, in certain cases, such as Stephen Hawking's, the outcome is close to a miracle. ■

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