ΤΕΛΕΤΗ ΑΝΑΓΟΡΕΥΣΗΣ ΤΟΥ ΚΑΘΗΓΗΤΗ
ANDREW VITERBI ΣΕ ΕΠΙΤΙΜΟ ΔΙΔΑΚΤΟΡΑ
ΤΗΣ ΣΧΟΛΗΣ ΘΕΤΙΚΩΝ ΚΑΙ ΕΦΑΡΜΟΣΜΕΝΩΝ ΕΠΙΣΤΗΜΩΝ ΚΑΙ ΤΗΣ
ΠΟΛΥΤΕΧΝΙΚΗΣ ΣΧΟΛΗΣ ΤΟΥ ΠΑΝΕΠΙΣΤΗΜΙΟΥ ΚΥΠΡΟΥ
Το έργο και την προσωπικότητα του Καθηγητή Andrew Viterbi παρουσιάζει
ο Καθηγητής του Τμήματος Πληροφορικής
Ανδρέας Πιτσιλλίδης
5 Μαρτίου 2010

AWARD OF AN HONORARY DOCTORATE
TO **ANDREW J. VITERBI**
BY THE FACULTY OF PURE AND APPLIED SCIENCES
AND FACULTY OF ENGINEERING
Friday, 5th of March 2010
7:00 p.m. Ceremonies Hall
at the University Campus (Kallipoleos street)

The work and persona of Professor Andrew Viterbi is presented by Professor Andreas Pitsillides of the Computer Science Department

Το Έργο και η Προσωπικότητα του Καθηγητή Andrew Viterbi (The work and persona of Prof. Andrew Viterbi)

Κύριε Πρύτανη, Κύριοι Αντιπρυτάνεις, Κύριε Κοσμήτορα της Σχολής Θετικών και Εφαρμοσμένων Επιστημών, Κύριε Κοσμήτορα της Πολυτεχνικής Σχολής, Κύριε Πρόεδρε του Τμήματος Πληροφορικής, κύριε Πρόεδρε του Τμήματος Ηλεκτρολόγων Μηχανικών και Μηχανικών Υπολογιστών, Αγαπητοί συνάδελφοι και φοιτητές, Εκλεκτοί Προσκεκλημένοι, Κυρίες και Κύριοι:

[Please allow me to continue in English for the benefit of our esteemed guest].

It is with **great** pleasure, and I **am honoured** to stand here, in front of you, to present, on behalf of the departments of Computer Science and Electrical and Computer Engineering the work and persona of a truly distinguished individual, who not only excelled as an Academic, but also as an Entrepreneur, Prof Andrew Viterbi, who is today being awarded an Honorary Doctorate by both the Department of Computer Science and of Electrical and Computer Engineering. The presence of two departments is indicative of the immensity, and cross applicability of Prof Viterbi's contribution in shaping Digital Communications, as we know it today. Try to imagine a world without Prof Viterbi's inventions, and you'd have to travel back in time 40 years or so — before cell phones, direct broadcast satellite TV, digital TV, speech recognition, video transmissions from the surface of Mars, and so on...

The co-founder of QUALCOMM, and the inventor of the Viterbi algorithm, started life as a penniless **Jewish refugee** who fled Italy for the United States on the brink of World War II. He was born in Bergamo, Italy, in 1935. This was a turbulent time in Europe and the Viterbis left in August 1939. Andrea, then aged four, landed in New York. In the English-speaking world, Andrea was regarded as a female name, so his name was changed to Andrew.

In kindergarten, he wrestled with learning English. In 1941, his family moved from New York City to Boston; his father Achille, then 60, struggled to re-establish his ophthalmology practice this side of the Atlantic, while his 47-year-old mother, Maria Luria, did her best to make a home. By age 10, Andrew often gazed across the Charles River at the buildings of the Massachusetts Institute of Technology, commonly known as MIT, determined to go there for college. And hard he worked to realize his dream: and he excelled, winning a **scholarship to MIT**. He enrolled in the co-op program in Electrical Engineering, which allowed him to work part-time to earn his keep. He entered as a freshman in 1952, studying electronics and communications theory under such renowned scholars as Norbert Wiener, Claude Shannon, Bruno Rossi and Roberto Fano. At MIT he progressed rapidly and in just five years he earned both his bachelor's and master's degrees in Electrical Engineering.

In June 1957, the 22-year-old accepted the most intriguing job. He joined a communications research centre—not only for artificial satellites but also for spacecraft to be launched to other planets over distances so vast that data signals were buried in radio noise from the sun and the galaxy. While there, he was one of the first communication engineers to recognize the potential and propose digital transmission techniques for space and satellite telecommunication systems.

Andrew Viterbi met and **married Erna Finci** in 1958, herself a Jewish refugee from Yugoslavia. She became his lifetime partner, sharing in all major decisions, and she was usually by his side as he scribbled notes on communication theory at home or at family gatherings. We are privileged to have Mrs Viterbi here, and we would like to thank her for being with us tonight.

The new MIT graduate and his family **moved to California**, home to defence industry giants. He went to work at the California Institute of Technology's **JPL**, Jet Propulsion Laboratory, then a center for communications and satellite control systems, which soon became part of a new National Aeronautics and Space Administration. There, he specialized in the communications technology of "spread spectrum" systems on a team that designed the telemetry equipment for the first successful U.S. satellite, Explorer 1.

In 1961, working part-time, he earned his **Ph.D. on error correcting codes** in Electrical Engineering from the University of Southern California, then a much less well known private university and the only school that would allow him to pursue part-time graduate work while working full-time. Now, as we all know, it is among the top US universities, with Prof Max Nikias, a Cypriot by birth, serving as executive Vice President and Provost.

Back to Professor Viterbi. As much as he enjoyed research at JPL, what he wanted to do was teach. So, a year after receiving his doctorate in 1962, he accepted an invitation to become an assistant professor at the University of California, Los Angeles (**UCLA**). For 10 years, Viterbi taught digital communications and information theory at UCLA's School of Engineering and Applied Science, and that's where the Viterbi Algorithm was incepted in early 1966.

In 1968 he put his theory into action when he cofounded **Linkabit Corp**. He formally resigned from UCLA in 1975 after he had moved to San Diego in 1973 and became a full-time Linkabit employee, but he stayed on at **UCSD** as an adjunct Professor. By the early 1980's Linkabit was sold, and in 1985 while between companies, UCSD gave him a regular Professorship appointment, on a part time basis, because he felt he wanted to do other things as well. For roughly the next ten years he was a quarter time professor. In late 1985, when the opportunity came up to start a new company, QUALCOMM, with the same people he had worked with at Linkabit, including Irwin Jacobs, it was too much of an incentive to resist joining.

In March 2000, Dr.Viterbi, then 65, stepped down as vice chairman and chief technology officer of QUALCOMM, saying, “It’s the right time to turn a page and widen one’s horizons’’, which is what he has been doing for the past 10 years. QUALCOMM was already a FORTUNE 500 company.

I will touch upon his entrepreneurial activities later. As far as academia is concerned, I would like to reiterate that Prof Viterbi, captivated with scholarship, remained very close throughout his career, even after he ‘officially’ retired. Since early in his career, Prof Viterbi held academic appointments at UCLA and then UC San Diego. In 1994, he became a UCSD Professor Emeritus, and since 2004 he is the Presidential Chair Visiting Professor at the University of Southern California.

Nowadays, he and Erna live in La Jolla, California. They have two sons and a daughter and several grandchildren, which I am sure keep them very busy, but fill them up with immense joy.

This of course is only a very brief glimpse of the history and the rich life of Prof Viterbi. I will now address aspects of **his work and its significance** to the world.

Andrew Viterbi, a visionary thinker and practitioner, opened the doors to the digital wireless communication age with the Viterbi Algorithm, published in 1967, a groundbreaking mathematical formula that enables clear and practically error-free radio communication, even from faraway moving low power radio transmitters and receivers. Considering all possible error sources in radio transmission, it is a wonder that communication succeeds. Both **noise**, especially as the signal power diminishes in relation to its power, and the **mobility** of transmitters and receivers, due to the shifting frequency problem (the Doppler shift) posed what appeared to be an insurmountable obstacle for the recovery of the signals. Prof Viterbi’s solutions addressed this problem in an elegant fashion.

It is no accident that today, more than 40 years after its invention, the Viterbi Algorithm is used in all international standards for digital cellular telephones, as well as many other diverse fields.

The **Viterbi Algorithm**, is **an efficient recursive optimal solution to the problem of estimating the state sequence of a discrete time finite-state Markov process observed in memoryless noise.** Many areas in communications and beyond can be cast in this form.

The problem of extracting the useful signal in the presence of noise, is of course not a problem of now. Since ancient times, when man realised the need to communicate further than what his voice would carry, started inventing various ingenious techniques, whose principles we carry over today. Man realised early that certain channels can carry information further by modulating, or encoding, the information onto a carrier and then transmitting through a channel. Examples include script carried by a horse-back messenger, smoke signals in open space, e-m radio waves in open space, electricity in wires, and light in fibre optic cables. For example, smoke signals could encode information like enemy is approaching by using specific codes, as for example smoke-no smoke-smoke. More complex techniques continued to be invented including the Morse-Code sent over wires as an electrical signal, or even analog voice and TV signals, sent over radio waves. **In all cases noise was a prohibitive factor in the reliable transfer of information to faraway places**. The further the signal travels, the more it is attenuated and consequently the more it suffers from the effect of the ambient noise.

However, a major breakthrough in the fight against noise was the realisation of **digital communications** in the earlier part of the 20th century. Basically, by using only two levels (that is a **binary signal**) for the transmission of coded information, it can be shown that we can be more resilient in the presence of quite a bit of noise in the channel. Furthermore, by building **redundancy** into the transmitted string, that is representing a binary 'one' or a binary 'zero' with more bits, and forcing certain bit-patterns only to be valid, we can aid in bit error correction. Going a step further, **convolution encoding** deliberately introduces correlation or memory into the input data sequence codes, in a known way. Now, we may guess our transmitted bits with higher confidence by exploiting this dependence on previous symbols. Professor Viterbi exploited just that to design an optimum Maximum Likelihood Decoder, of reduced complexity and improved performance, the celebrated **Viterbi Algorithm**. Therefore, **using together a convolutional encoder and a Viterbi decoder almost 100% error free communication over a noisy communications channel can be provided.**

The Viterbi algorithm is applied on the possibly corrupted received signal sequence, intelligently sorting through the labyrinth of ones and zeros, to find the most likely sequence representing the original message. It **applies maximum-likelihood principles, or forward dynamic programming, performing an optimal exhaustive search**, to limit the comparisons to an extremely small number of surviving paths at each step, instead of checking all possible combinations of paths. The observation is this: the shortest complete path at each state of the route must begin with one of these survivors. Thus at any time step we need remember only the survivors and their cumulative costs, in addition to keeping track of their path up to that point. Basically, at each iteration of the algorithm we throw away more and more improbable paths, and the recursion proceeds likewise. In continuous mode, the decoder waits until it has processed a number of symbols greater than the traceback length and then it starts delivering output bits. The longer the traceback lengh of the path is, the higher our confidence in correcting any errors; typically the traceback period rarely exceeding 60. The algorithm decodes very fast, with predicted delay, which is necessary in order to use it in real time at full communication speeds.

Looking back in time one can say that it was a natural progression for Prof. Viterbi to turn his attention to **CDMA – Code Division Multiple Access**, the standard used by all 3rd generation cellular networks of today. Having already solved the problem of communicating in the presence of noise, the question was whether multiple users could communicate successfully over the same channel, with each communicating pair using their own different codes (in other words their own language). As it turns out, the answer is yes, since other users of the channel appear as noise to them. However, as Prof. Viterbi astutely responded to Klein Gilhousen when one day he asked, "Why can't we use this (meaning the Viterbi algorithm) for cellular? There's lots of interference there." He said: "That sounds familiar, but you've got a power control problem. You have got to assure that no one is swamping out your signal." Thus, if power can be kept down to tolerable controlled levels, we can have multiple users communicating over the same channel. As a matter of fact, quite a few users could use the channel, much more than other competing techniques, as for example 3 to 4 times more than TDMA and FDMA, used by the GSM mobile network. As it turns out, sophisticated power control is necessary in order to implement CDMA, and that is what QUALCOMM and others have refined over the years. As Prof. Viterbi recalls, they came up with a really clean and neat way of combining what they called open loop and closed loop power control, and it worked very well. The aim is to keep all the user's signal energy at the base station nearly equal in the shared channel, and also to ensure that each user transmits only as much energy as is required to maintain a given level of error performance; thus prolonging the mobile phone's battery life.

Professor Viterbi need not have **published** any further than his seminal 1967 paper to significantly contribute to society. He has however made time to continue conducting fundamental research in digital communications theory and publish his findings in leading journals as well as write books, especially on the uses of the Viterbi algorithm and CDMA.

Dr. Viterbi's first internationally regarded book, Principles of Coherent Communications, appeared in 1966. A second, Principles of Digital Communications and Coding, followed in 1979, and a third Book on CDMA: Principles of Spread Spectrum Communication, was published in 1995. Dr Viterbi has also published numerous academic papers, including contributions on phase locked loops in his early career, and later on CDMA and power control.

A search in Amazon books of the word Viterbi returns over 300 books, from many diverse fields of application. Looking at the citations, the first page of Google scholar lists about 13,000 direct citations to his work, plus who knows how many more indirect references to the Viterbi Algorithm.

But, what is even more impressive of its **impact** is the **usage** of Prof Viterbi's algorithm. As we speak now, approximately 10^{15} bits per second (that is over 1,000 trillion bits) are being decoded by the Viterbi Algorithm in digital TV sets around the world, every second of every day, making it by far the largest current consumer of Viterbi Algorithm cycles. And that figure does not include the hundreds of millions of mobile telephones, currently chatting around the world. Viterbi Algorithm decoders are currently used in about one billion mobile phones, which is probably the largest number in any application.

The Viterbi algorithm has been shown to not only be useful in communication problems, but also in many diverse fields, becoming a general-purpose algorithm for decoding Hidden Markov Models. As G. David Forney states in his 1972 paper on the 'The Viterbi Algorithm': ''Our belief is that the algorithm will find application in an increasing diversity of areas''. How prophetic... The number of applications are indeed numerous, including decoding the convolutional codes used in both CDMA and GSM digital cellular, dial-up modems, satellite, digital TV, deep-space communications, and 802.11 wireless LANs. It is now also commonly used in speech recognition, keyword spotting, computational linguistics, bioinformatics, e.g., to locate genes in DNA sequences, and also in search engines. The Viterbi Algorithm has even found its way into some of our work, in helping us find the k-best disjoint paths through a communication network, transformed into a Trellis graph.

Before I turn my attention to Prof Viterbi's truly impressive entrepreneurship, I would like to take the opportunity to highlight **a couple of general points**, with an intended target our young researchers and the funding bodies.

At the time of the Viterbi Algorithm invention only a handful of computers in the world could perform the millions of operations required by this revolutionary algorithm. However, as we now know, time and Moore's law would eventually catch up with his vision. As Prof Viterbi recalls in a 1999 interview: "the Viterbi algorithm for convolutional codes . . . came out of my teaching . . . . I found information theory difficult to teach, so I started developing some tools. . . . I wrote the first paper in March '66, but it wasn't published until April '67. . . At one point I was actually discouraged from publishing the algorithm details. Fortunately, one of the reviewers, Jim Massey, encouraged me to include the algorithm''. And continues to say that not many thought that it had any potential for practical value, including the lawyer who discouraged him from seeking a patent on his algorithm. Especially, for young researchers this can be a point to remember. Fundamental research is worthy of pursuing. But persist. If your work is worthy it will eventually be published. Also, fundamental research should be allowed to flourish, without the latest trends in 'targeted research' and commercial 'exploitation' as the only value... If Prof Viterbi wrote a research proposal on this topic then, with today's criteria, he would had most probably been rejected. In a recent interview regarding federal spending on research and development Prof Viterbi noted: ''I am a member of Clinton's Presidential Information Technology Advisory Committee, and we just put out a report urging the government to continue doing basic R&D. Not application oriented research, but fundamental research. ... This kind of research is not going to be carried on by industry because shareholders won't allow it. ... As for where it should be done, I think it possibly should be done in the universities.''

Turning our attention now to **Entrepreneurship**, his innovative spirit and willingness to help society are evident. Even beyond his retirement from QUALCOMM at the age of 65, in 2000, he has founded the Viterbi Group, a company which advises and invests in start-up companies, predominantly in wireless communications, network infrastructure and imaging.

Visionary ideas seemed to feed his entrepreneurial appetite from early on his career. In the spring of 1967, Dr. Viterbi met Irwin Jacobs at a telecommunications conference in California. Both men, and another of Dr. Viterbi's colleagues, Leonard Kleinrock, shared an interest in forming Linkabit. The company grew as it supplied software for government computers and performed simulations using the Viterbi Algorithm. By the 1970s, Linkabit began providing technology for defence communications satellites. There he served as Executive Vice President and later as President. He left in 1985, 5 years after Linkabit was sold. In July 1985, Dr. Viterbi co-founded QUALCOMM, a developer and manufacturer of mobile satellite communications and digital wireless telephony, where he served as Chief Technical Officer and Vice Chairman until 2000 when he retired. When its doors opened in 1985, Dr. Viterbi was respected across the globe for his innovative ideas, as well as his uncanny ability to turn scientific discoveries into profitable enterprises. Under his leadership, QUALCOMM received international recognition for innovative technology, holding more than 1000 patents, in the areas of digital wireless communication systems and products based on Code Division Multiple Access (CDMA) technologies. QUALCOMM went from seven employees in 1985 to a peak of more than 10,000 in 1999. The rest is history, with 100's of installed CDMA Telecommunication systems and 100's of millions of CDMA phones worldwide.

Finally, I must also stress Andrew and Erna Viterbi;'s other **contribution to humanity**, as **philanthropists**, through the Viterbi Family Foundation.

But first, Professor Viterbi appears to be a family man. As Erna states in the Andrew and Erna Viterbi video: ''The Journey and the Legacy'', available through the Viterbi Museum, at the USC Viterbi School of Engineering: ''The kids were always around him, however it did not stop him from working, he would put them in his lap, and he would carry on working. .... He always came home happy from work and every day he left happily for work, but he also came home happily''.

Now retired from industry, Prof Viterbi devotes his time and energy encouraging bright young engineers in developing new technologies, through both philanthropy and venture capital. After he retired from QUALCOMM, when not serving on the boards of 13 companies and not-for-profit organizations, he devotes his remaining time three ways: professional activities (such as writing review papers and giving lectures at universities and keynote addresses at conferences), investment in start-up companies ("I get a kick out of companies with new technologies going after established or emerging markets—and I want to make money, like any other investor!", he says), and philanthropy through the Viterbi Family Foundation.

The foundation's largest endowment was $52 million to the engineering school of the University of Southern California in 2004. The university then renamed the school the Andrew and Erna Viterbi School of Engineering, now ranked among the top 10 engineering schools in the country. Other grants have gone to his former high school (the Boston Latin School in Boston), to Scripps Research Institute, to MIT, to Technion in Israel, and to various programs preparing disadvantaged young people for higher education.

Living in Southern California, he is now primarily focused on his family, travel, and the future of telecommunications, which he says is both in broadband access and issues of digital security." Who knows, maybe soon he will surprise us with some answers on the question he posed on his keynote speech last Wednesday in Limassol on whether there are any societal implications of the Markov Property, and if memory matters. His initial thoughts are that perhaps for the individuals yes. But not for the society!?

In any case, his legacy goes on. Viterbi's daughter Audrey is a Ph.D. graduate involved in communications (and a co-founder of Viterbi Group), son Alan is an entrepreneur, and son Alexander is an expert in digital cinema.

For his contribution to society, Prof Viterbi has been honoured in many occasions. He is rightly celebrated as one of the leading communications engineers and theorists of the twentieth century. He has received almost every professional award possible, including election not only to the **National Academy of Sciences** (USA) in 1997, but also to the **National Academy of Engineering** (USA) in 1978, and to the **American Academy of Arts and Sciences** (USA) in 2001. His award citations usually cite "invention of the Viterbi algorithm" as his most notable accomplishment.

The very long list of his **major awards** reads as follows:

- The Cristoforo Colombo Medal, Genova and CNR, one of Italy's National Research Council highest academic accolades, in 1975
- The IEEE Alexander Graham Bell Medal, in 1984
- The University of Southern California Outstanding Engineering Alumnus, in 1986

- The Marconi International Fellowship Award, in 1990
- The Shannon Award and Lecture, IEEE Information Theory Society, considered the highest honour in Information Theory and Applications, in 1991
- The NEC C&C Award, Japan, in 1992
- The Eduard Rhein Foundation Basic Research Award, Germany, in 1994
- The "Grande Ufficiale della Repubblica" awarded by President of Italy, in 2001
- The James Clerk Maxwell Award, IEEE and Royal Society of Edinburgh, in 2007
- The Robert Noyes Award, Semiconductor Industry Association, in 2007
- The U.S. National Medal of Science, for developing "the 'Viterbi algorithm,' and for his contributions to Code Division Multiple Access (CDMA) wireless technology that transformed the theory and practice of digital communications.", in 2007
- The Millennium Laureate, Technology Academy Finland, *"For the invention of the Viterbi algorithm, the key building element in modern wireless and digital communications systems, touching the lives of people everywhere.",* in 2008
- The IEEE Medal of Honour, which reads ''the *IEEE Life Fellow Andrew J. Viterbi, co-founder of QUALCOMM Incorporated and developer of wireless technologies that became the international standard for third-generation cellular phones, has been named the 2010 IEEE Medal of Honor recipient ... The IEEE's highest award, will be presented 26 June 2010.''*

Furthermore, his list of 7 **Honorary Degrees include:**

- The University of Waterloo, Ontario, Canada, in 1990
- The University of Rome, Tor Vergata, in 1997
- The Technion, Israel Institute of Technology, in 2000
- The University of Notre Dame, in 2001
- The University of Rome, La Sapienza, in 2004
- The University of Southern California, in 2006
- The Polytechnic Institute of New York University, in 2009

Beyond that from 1997 until 2001, he served as a member of the U.S. President's Information Technology Advisory Committee. He is currently a trustee of the University of Southern California, a Board Member of the Burnham Institute and the Scripps Research Institute in La Jolla, and a trustee of the Mathematical Sciences Research Institute in Berkeley.

In closing, I would like to **summarise his major achievements**:

Prof Viterbi's revolutionary and creative work in the late 20th century **ushered in the mobile digital communication age**. His most famous discovery, the **Viterbi Algorithm**, is a mathematical system for retrieving the original voice or data message from a coded digital stream and is found in billions of cell phone devices. Viterbi is also one of the creators of the **CDMA** spread spectrum approach, which is an *international standard for third-generation cellular phones.*

Prof Viterbi not only had an extraordinarily prolific **academic career**, but he simultaneously excelled as a **business entrepreneur**. He co-founded two hugely successful companies, **Linkabit**, which marketed digital technologies based on the Viterbi Algorithm, and the San Diego cell phone technology giant, **QUALCOMM**. In actual fact, no one deserves more credit for this tremendously important invention and its subsequent application to such widespread application, than its actual inventor.

Prof Viterbi has forever **changed Digital Communications, and thus how people everywhere connect and communicate**, whether from across a crowded city, between nations or from the infinite reaches of space. He is a pioneer in the global spread of wireless communications and a visionary engineer and entrepreneur who gave birth to today's cellular technology that connects hundreds of millions of people.

Professor Viterbi, the University of Cyprus, in recognition of your extraordinary contribution to academia and society in general, joins the other 7 universities around the world, in honouring you with an honorary Doctorate, the highest honour this university can bestow.

Equally, we are indeed privileged by your acceptance and presence here at the University of Cyprus, and I hope you are enjoying your stay in Cyprus.