HOW INFORMATION THEORY CHANGED THE WORLD –

A BRIEF REVIEW OF THE HISTORY OF THE INFORMATION THEORY SOCIETY

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ABSTRACT

A remarkable paper by Claude Shannon published in 1948, that introduced the modern and meaningful way of thinking about communication of information, had a formidable impact on technology and on the emergence of the Information era. At the same time it spawned the Information Theory Society of the IEEE that has carried the torch of Shannon's ideas and continues to push the frontiers of the fundamental foundations of general communication theory and technology. This paper reviews briefly this unique and illustrious trajectory of this Society.

INTRODUCTION

Although co-authored by Claude Shannon and Weaver, the famous paper titled "A Mathematical Theory of Communication" was the brainchild of Claude Shannon alone. As evidenced from the totality of his research contributions, Shannon possessed an uncanny ability to dissect a thorny issue, detect its core, and retain only its essential components. This paper was no exception. It formulated the encoding and transmission of information in a simple but profound manner and laid the foundation for a torrent of productive research that ensued for the last sixty-some years and that has literally enabled the revolutionary developments that, along with the miniaturization of hardware, changed the way we live and yielded a remarkable increase in worldwide productivity and prosperity.

As soon as the scientific community read and comprehended the ideas of Shannon, the discipline of Information Theory spread like an avalanche. Sponsored by the Institute of Radio Engineers (IRE), the first Symposium on Information Theory was held in London in 1950. The Professional Group of Information Theory (PGIT) was formally constituted in 1951 and it proceeded to hold

its first International Symposium in 1952 in New York City. In Russia, Aleksandra Khinchine and others and in England, Philip Woodward and others became apostles of the idea of Information Theory and joined a worldwide mushrooming interest in this young and fascinating discipline. In 1995 the first issue of the IRE Transactions on Information Theory was published and one of its contents was a famous short paper by Shannon, called "The Bandwagon", in which Shannon cautioned against the thoughtless, facile, and arbitrary adoption and misuse of his ideas in dozens of other disciplines and domains, ranging from Philosophy and Religion to all manner of applications. The seed had already grown and spread. It was time to manage its growth carefully.

THE MAIN LANDMARKS

After its formation, PGIT continued its steady growth and activities within the framework of IRE. In 1964, when IEEE was formed, and into which the IRE was folded, the PGIT became known as the IEEE Information Theory Group. Its main activities consisted of publishing its Transactions on a bi-monthly basis and of holding its International Symposium more or less every 18 months. Around 1969 the first rumblings of the "first" death of Information Theory were heard. Simply put, Shannon's quintessential idea was that every channel had a **capacity** which represented the maximum achievable rate at which Information could be reliably transmitted. Furthermore, it promised that this capacity could be achieved by means of specific encoding procedures. By 1969 people were frustrated to see that, although almost all codes could achieve capacity in theory, all the codes that we could think of did not. Thus, there was a sentiment of discouragement that undermined the original enthusiasm that had sustained the discipline for twenty years.

Yet, before the community could "bury" it, the discipline was reinvigorated by the explicit construction of codes by Justensen that could indeed achieve capacity. This remarkable development was announced at the 1971 International Symposium on Information Theory in Monterey, California, and marked a resurgence of interest in, and vitality of, the field.

In 1973 the Institution of the Shannon Lecture was established. It became eventually a formal award by the Society and represented the highest recognition of lifelong contributions to, and achievement, in the field. The first such lecture was given by Claude Shannon, himself, in the International Symposium of the Society in Ashkelon, Israel. It was an insightful and entertaining lecture that playfully expanded on the nature of the notion of feedback.

During the decade of the '70's, Information Theory started being applied. First in deep space and satellite communications and then in data transmission over telephone lines, Information Theory-inspired codes were developed that resulted in increased rates of reliable communication.

In 1986 the Society decided to hold its 1991 Symposium in Budapest, Hungary, hailing its decision as a landmark, since it would be the first ever major IEEE-sponsored event in a communist country. As we know now, this conference ended up being the first IEEE conference in an ex-communist country, since the momentous events of 1989 swept away the iron curtain and caused the demise of the communist regimes in Europe.

In 1993 another major breakthrough occurred that pushed the envelope of applicability of Information Theory almost to its limits. Almost by accident, the so-called Turbo-codes were invented, they possessed two remarkable properties: (i) they came within fractions of a db in achieving capacity, and (ii) they were easily and practically implementable. To this date, there is continuing activity on this discovery.

Shortly after that, the seminal ideas of Multi-input/Multi-output (MIMO) technology emerged and formed the foundations of the so-called space-time codes that changed the landscape in Wireless Communications. In essence, the use of multiple antenna elements at both transmitter and receiver in a point-to-point communication link increases the capacity of that link by a factor equal to the number of such antenna elements. Furthermore, space-time codes are the means to come close to realizing this expanded capacity. Finally, perhaps more importantly, these ideas led to their adaptation in wireless network environments opening up the possibility of applying Information Theory to entire network systems.

In 1995, at long last, the "Information Theory Group" dropped its resistance against renaming itself "Information Theory Society" and thus became the **last** professional group to join the community of IEEE Societies. A crucial factor in this decision was the announced intent by IEEE to refer to this entity as the "Information Theory Group Society", if it failed to agree to the name change.

The year 2001 marked the passing of Claude Shannon who, unfortunately, was plagued by the ravages of Alzheimer's disease for the last ten, or so, years of his life.

Today, the Society is thriving. Its future plans include holding its International Symposium in Austin, Texas (2010), St. Petersburg, Russia (2011), Boston, Massachusetts (2012), Turkey (2013), and then Hong Kong (2015). As of 2000, the Symposium became an annual affair, moving away from the odd interval of 18 months between successive Symposia.

Also, as of the mid-seventies, the Symposia were complemented by International Workshops that take place irregularly but frequently (often more than twice per year) in locales literally around the world.

THE "UNIQUENESS" OF THE SOCIETY

Perhaps reflecting the idiosyncratic nature of many of its members, the Society enjoys some unique characteristics that have created a reputation of eccentricity. The list of these characteristics is long but its main components are the following:

(i) It is the only Society (and field) to have sprung out of a single paper

(ii) It is the last professional group within the IEEE to convert to Society status

(iii) Its Symposium (at least until 2000) was held every 18 months and its Transactions were (until early in this century) bi-monthly

(iv) It is characterized by the strongest mixture of Mathematics and Engineering; perhaps because of that reason it had become in the late seventies a target and a "punch-bag" for the infamous candidate for the presidency of IEEE, Irwin Feerst, whose wrath it received

in frequent tirades that accused its Transactions of being so incomprehensible that it did not matter whether it was held upside-down or right-side up. To which a renowned member of the Society responded, in humor that is characteristic across the membership, that this was natural since it uses the … binary system

(v) It has been perennially small, fluctuating over the years between the levels of 3,000 and 5,000 members

(vi) Finally, it is the only Society (and discipline) that has suffered multiple "deaths" and subsequent "births".

THE BIRTH-DEATH PROCESS

As mentioned earlier, in 1969 (or there about), the Society suffered its first "death"; what this means is that several members of the Engineering Community with a short fuse, became impatient with the failure to provide "good" codes (that is, capacity-achieving codes) and were quick to spread the rumor that Information Theory was irrelevant and belonged to the margins. Of course, in 1971 the Justesen codes marked a persuasive rebuttal to this rumor, thereby causing the field's second "birth", as it were.

Then, around the early '80's the revolutionary development of optical fiber technology came along. It promised almost unlimited bit-rates and practically zero noise. Hence, once again, many people were quick to declare the "irrelevance" of Information Theory. In a famous keynote address at an Information Theory workshop in Caesaria, Israel, in 1984, Bob Lucky asked rhetorically "who needs Communication Theory?" and provided the answer that "we, Communication theorists" are the only ones who do, since fiber can cover our transmission needs without the help of any coding.

Before the ink dried on Lucky's thesis, however, the wireless revolution was taking off, providing thereby a new fertile field of applicability for Information Theory. Hence, a third "birth" of the field took place.

Soon thereafter, around 1993, another momentous event took place in the telecommunication arena, the famous (or infamous) "deregulation". "Lucky strikes again", as the title of his collection of witty columns from the Spectrum suggests, and a third "death" of Information Theory is declared as a consequence of the deregulation.

Yet, like "Deus ex-machinae", Turbo codes are invented (or more correctly, discovered) just in time to cause yet another rebirth of the field, with the emergence of MIMO technology and space-time coding in rapid succession, pushing the field into a healthy, if not "booming", state.

In around 1998, during the golden anniversary of the field's first birth, the Society celebrated with a landmark Symposium in Cambridge, Massachusetts. Somewhat in jest, people proposed to celebrate the success storey of Information Theory (capacity, at least for the additive while Gaussian noise channel, had been achieved) and declare the whole thing over; in other words another "death" of sorts, albeit of a benign variety.

And yet, just as at the time of earlier deaths, a new catalytic event caused an immediate rebirth. The observation that the union between Information Theory and Networking lay "unconsummated", opened up a new vista of applicability of the discipline to the vast field of wireless (**and** wireline) networking.

As a result, at least for the time being, Information Theory is enjoying a robust "fifth" life with no signs of another "death" in the horizon.

IMPACT

The thread of applicability of Information Theory to Engineering Practice is not as long as many believe. In fact, many shining examples abound of spectacularly successful entrepreneurial endeavors by prominent Information Theorists. Andy Viterbi, through Linkabit and then Qualcomm, Dave Forney, through Codex that folded into Motorola, Elwyn Berlekamp, through Cyclotomics that folded into Kodak, Chris Heegard, through Alantro that folded into Texas Instruments, Jim Omura, through Cylink, that folded into Safenet, are some examples which along with many other untold enterprises dot the map of the Information Technology revolution and tell the story of success that the Ideas of Information Theory have created.

The impact of the discipline, however, extends to other fields as well. Unlike the rapid and hurried wave of enthusiasm that marked the early '50's and caused Shannon's "Bandwagon" article, the spread to other disciplines has been slow but educated and substantive. The connection to Mathematics (including Analysis, Algebra, Topology, and Probability Theory and Statistics) which is well-known and obvious has led to direct contributions to these fields of Mathematics.

Information Theory enjoys also a, perhaps not equally obvious, connection to Physics. It is intimately connected to Optics, Electromagnetism, and Quantum Mechanics. Recent advances in Quantum computing have substantiated the significance of this connection.

Computer Science and Engineering is another field that has benefited from Information Theory. Aspects of compression, computational complexity, algorithms, and switching design have felt the beneficial

effects of Information-theoretic thinking. After all, it was Shannon himself who worked on Boolean logic and circuit design for his M.S. Thesis.

The effect on security, that the formal foundation of Cryptography has caused, is major. It continues to bear the imprint of the ideas of public key cryptography generated by Information Theory that are pervasive in today's encryption standards.

Biology is one of the most recent areas of applicability of Information Theory. Again, leaving aside the fact that Shannon's Ph.D. dissertation was on the subject of genetics, we are witnessing today a serious connection between genetic code and the foundational ideas of Information Theory.

Economics, Networking, and Control Theory are some additional disciplines that are currently feeling the impact of their intrinsic connection to the flow of information.

CONCLUSION

It may be appropriate to close this brief survey with a quote, so typical of the humor of Information Theory disciples, that exemplifies the contribution (in jest) of Information Theory to National Security, and, at the same time, inoculates the field against the skepticism that has surrounded it from different quarters and that has led to its "multiple deaths". When in the mid-seventies funding agencies were critical of Information Theory as not having had an impact on the country's needs, the response, according to the "lore" within the Society, was that, of course Information Theory has contributed to the security of the United States. How? By getting the Russians interested in the (useless) field of Information Theory itself!