Thoughts on analogies

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INAUGURAL ADDRESS BY

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Gentlemen of the Board of Trustees,
Mr. Secretary of the University,
Members of the Directorate of the
"Stichting Eindhovens Hogeschoolfonds",
Members of the Senate,
Members of the academic, administrative
and technical staffs,
Students,
and all of you who are showing your
interest by your presence here,

Ladies and Gentlemen,

With your permission, I will begin my address with a family anecdote. When my older daughter finished her American Secondary school I sent her for a year's study in the Gymnase de Neuchâtel, where I had studied in my time. Her professor of chemistry, who was a former schoolmate of mine, welcomed her warmly and told her how well he remembered her father, and how he recalled particularly his flaming red hair, and his pronounced French accent in English class. -And my daughter said: "He still has the accent".

I do hope that the Dutch audience I have the honor of addressing in English will understand me well, French accent and all, when I say something of the subjects I propose to teach, and when I endeavour to say something also about my scientific philosophy and my faith as a person.

The name of my chair is the Science of Analogies. This name was imaginatively selected by Professor ROETERINK and Professor KEULEMANS who considered that the good fortune I have had with several technical ideas was due in no small part to an exploitation of the analogies which exist between electrical circuits, mechanical circuits, pneumatic circuits, and thermal circuits.

Many years ago the oscillating electrical circuit was explained by analogy with a vibrating mechanical system. But to-day the symbolism

of communication theory has been developed to the point where it is readily applicable to non-electrical systems. The very use of the word "circuit" for such systems is symptomatic of this trend.

Accordingly many of the subjects I will teach are the application of communication theory to inventions and developments in other fields. Thus, in the field of radiation detection, a discussion of the electrical equivalent circuits of the thermocouple and of the pneumatic infrared detector can serve to give a more than superficial insight into the fundamental sensitivity limits of these two detectors. In the case of the pneumatic detector, which is a miniature hot air engine, the electrical symbolism is fully adequate to represent not only the thermal parameters and the pneumatic parameters, but also the interaction of these parameters, which constitutes the principle of detection employed. Likewise, the so-called T-network of the communication engineer can be utilized with elegance to show the interconnection of the thermal and pneumatic parameters of a gas mass, and to derive directly several important thermodynamic relations.

Electrical analogues are applicable also to the study of diffusion phenomena, so important in gas chromatography. Five years ago the chromatographic column was shown to be governed by the same differential equation which governs the electrical transmission line, the so-called telegrapher's equation. Then, in order to put numbers in the formula, the chromatographic column was replaced in the calculations by a simple open tube. This mathematical device led to the finding that the separation efficiency of the packed column was only one hundreth of one per cent. This finding sparked the idea of replacing the packed column by the open tube first used as a mathematical model. Capillary Gas Chromatography resulted from this simple experiment.

However, the transfer of ideas between communication theory and mechanics or thermodynamics is not a one-way traffic.

Conventional electrical circuits are essentially one-dimensional, while mechanical models can be one-dimensional, two-dimensional or three-dimensional. Two-dimensional mechanical analogues can be utilized with advantage in connection with the vectorial representation of electrical quantities. This is particularly useful when studying frequency modulation transients which cannot be treated analytically. The mechanical model gives a visualization of the phenomena and this permits to obtain immediately qualitative answers which are often fully adequate.

I have applied this method to the study of a new communication technique called the phase-locked loop. This is a technique which permits to track with a very narrow reception bandwidth a continuous wave signal of extremely small magnitude having a frequency which may vary smoothly over an interval a million or a billion times wider than the bandwidth of its reception. There is in America a steadily growing interest in this technique, because it forms an essential part of the new extra terrestrial technology required for tracking, for instance, a one watt source carried in an instrumented planetoid having its own orbit around the sun. I realize that expenditures for so-called space research have been greater in the United States than elsewhere, but we should look to a pooling of European resources for space research similar to that accomplished at Cern for nuclear research. When this takes place I am sure Eindhoven will make contributions worthy of its name, and some preliminary studies and experiments in this field belong properly in a vital new technological university.

Some thirteen years ago an analogy made between a carrier current telephone line and an infrared spectrometer led to an optical development, multislit spectrometry, which is now only receiving the attention of the manufacturers of scientific instruments. The idea was simplicity itself: Instead of single entrance and exit slits in a monochromator, have several, arranged in pairs of corresponding slits, one of each pair at the entrance, and the other at the exit, and so located that radiation of the same wavelength is passed by the two slits of every pair. In this manner, you obtain much more of the radiation you wish to measure, but you obtain also a great quantity of unwanted radiation passing through non-corresponding slits. The effect of this unwanted radiation can be nullified if each pair of corresponding slits is treated like a separate communication channel in a carrier current system, by modulating the aperture of the entrance and exit slits. But the sinusoidal modulation of carrier current telephony is not so practical for a light beam as the simple on-off modulation of the optical shutter. This required the mathematical development of a binary modulation system in which a function of time can have only two values, zero or one. The experimental model incorporating these principles permitted to obtain, in one hundred milliseconds, infrared spectra which conventional systems required several minutes to produce.

The new instrumental principle evolved was not the only result of this development. The mathematical aspects were fully as captivating, for they led to a form of binary codes which I termed "complementary

series". And now the cycle is almost completed with a return to communication theory, because complementary series have been utilized for the theoretical solution of new communication problems arising in so-called horizontal modulation systems.

I should say a few words about these horizontals modulation system which are of growing importance. They are radio communication systems in which several stations share a common wide frequency band, much wider than is required for conventional communication channels utilizing amplitude or frequency modulation. Every station is assigned a code, which has the form of a semi-random sequence of several hundred "zeroes" and "ones". Any message intended for any one station is modulated in that station's code, so that it will be received by it only, and not by any other. Thus, there is no need to address anyone before sending the message, because the message itself contains its own address. Another feature of horizontal communication systems is their anti-jamming property. Anyone knowing the code in which to address another requires much less power to make himself understood than anyone else not knowing that code would require to mask the message with radio noise.

One method of realizing a horizontal modulation system consists in transforming a message into a signal consisting of sharp pulses, delaying this signal by several amounts, and re-assembling the variously delayed signals thus obtained in a manner which is determined by the code, so as to obtain a composite signal, which has superficially the character of radio noise. This noise like signal is transmitted. Meanwhile a similar delaying and re-assembling process is continuously being performed, on the received signals, at the various stations of the net, in accordance with their respective codes, and the message will be intelligible only for the station to which it is addressed, and which has used the proper code.

A tool for performing this delaying and re-assembling process exists. It is the dispersionless tapped delay line. I propose to discuss in my lectures the fundamental aspects of these delay lines. Their theory is compact and there are unsolved theoretical circuit problems which may challenge some of my listeners. Also, they have other potential applications in the fields of pattern recognition or learning machines in which interest is growing.

I have mentionned earlier certain binary codes, used in multislit spectroscopy, which I have termed complementary series, and also the semi-random codes which are useful in horizontal modulation systems. There are, of course, several other forms of binary coding.

Some of you may be more familiar with the error correcting codes of information theory. In organic chemistry it is possible to use topological codes to replace some of the awkwardly long names of hydrocarbon chains. All of these codes are related to number theory and to group theory, and share with these theories a character of the will of the wisp by being just as captivating, and just as frustating when interesting results are found impossible to generalize.

The useful analogies which we can find between electrical circuits and mechanical or thermal circuits, and the suggestive connections which we can make between number theory and the topology of a large hydrocarbon molecule, are facets of a general trend, for many of the recent scientific advances are due to the crossfertilization of, at first view, separate and distinct fields. Of all the disciplines leaving thus their seeds in others, communication theory is the most prolific, with its inroads in physics, in chemistry, in sociology through automation, in biology and philosophy through information theory. Communication theory or should I say communication philosophy, appears like an octopus with its tentacles stirring thought here, there, and everwhere, an octopus intimately linked to the development of social man, and to the reflections of individual man.

It is information theory which makes communication philosophy deserve its name. There are two aspects to information theory. One aspect is the essentially mathematical aspect of error correction coding, which I have mentioned earlier. The bulk of what has been written and organized in this field belongs indeed to error correction coding. The other aspect is more tenuous and difficult to define. It represents the attitude and the thoughts engendered by the existence of a measure of information content, and by the tantalizing parallel which can be made between the negentropy of information and the entropy of the thermodynamicist, that other scientific "enfant terrible" which made its impact on teleology by saying that there had been a creation of our Universe.

To be sure that measure of information is a brutal one - it is a measure of the information which MAXWELL'S demon lacks to operate his trapdoor, and all the information contained in all the books ever written would barely help the poor devil to separate one milligram of air into its slow and fast components. Will there ever be a measure of the patterns which constitute intelligent information, or will intelligence always transcend a measure of itself, by proving the meaninglessness of the question, or by leaving it an open question, with the same will of the wisp character as the proof or disproof of

some number theoretical surmise? Then, will the ever deeper mysteries to which research shall lead us be essentially mathematical in character?

These are some of the big questions which individual man asks. Hemmed in as he feels by finiteness, by the finite number of his brain cells and thoughts, by the surmised finiteness of his Universe, by the finiteness of his lifespan, he looks for infinitude in the higher values: the artistic, the intellectual, the spiritual values. And, forced by the factual disclosures of science to accept a monistic world in which pattern is identified with spirit, he finds himself face to face with nothingness, and casts about for new tenets. Renewed interest in existentialism, in neo-stoicism and in some of the Eastern spiritual disciplines are today's manifestations of man's anxiety about himself as an individual. And this anxiety about himself is paralleled by an anxiety about his society, manifested by an oft expressed fear of mass suicide of the human race.

Will a really conscientious man dare tell another what faith that other should have? Man can only educate another, tell him about the faiths of others, and give him the means of building his own faith, and make it so strong that he will not need the moral support derived from the presence of millions of others sharing the same faith. I am talking about an utopia now and I am doing it purposefully. Every effort and sacrifice we make to-day for education is aimed at this utopia, and the anxiety of man about his personal to-morrow and the to-morrow of his country should be mitigated by his high hopes for the eventual future of mankind.

Regardless of the possibility of future wars, in which a country hit may stay hit for a long time, may we not have the faith that the driving principles which made life out of inert matter, and man out of protoplasma, will continue to operate, in their up and down way in which the ups are always greater than the downs? May we not have the faith that victory will continue to have priority over defeat, intelligence over stupidity, and life over death?

An anthropologist, FATHER TEILHARD DE CHARDIN, whose work many of you have read, or will read, and whom history may judge as one of the great Judeo-Christian prophets, has had the imagination to establish a biological analogy between the development of large organic molecules into living cells, the subsequent development of living cells into intelligent organisms culminating in man, and the future development of man into an increasingly interwoven social organism. This powerful analogy has given him a vision of the

ultimate biological unit, the "thinking planet", in which a tighter association of man and his society will not make of the individual a "fourmi bleue" subjugated to and fearful of the greater pattern, as it does to-day in archaic Russia and China. Instead, it will promote emulative tensions, competition for learning and searching, and it will instill in the heart of the individual the same love for his planet which he has to-day for his family and for his endangered country.

But the ancestral form of society, a million years hence, is here to-day just as the ancestral forms of to-day's creatures were here a million years ago. An archeologist transported back in time a million years or even much would have little difficulty in recognizing these ancestral forms, and we can likewise speculate about the possible findings of the bio-sociologist of a million years hence who would find himself transported in our midst.

Would he find the ancestral form of his society in Russia's Marxism or in Spain's remnants of fascism? I think not. I believe that, as our archeologist friend travels from land to land in our present day society, his eyes would sparkle when discovering a small country well organized to wrest its very living space from nature, with a highly developed sense of law for the purpose of providing for the individual maximum freedom of expression and of learning, and freedom from want and from fear. A country in which greater sacrifices are made than in most to plan for the future, educate the young, and provide the sinews of research.

It is not a desire to pay mere compliments; it is a desire to give expression to my thought which makes me say our imaginary visitor would find an ancestral form of his society in these Netherlands of gentle rains, beautiful flowers, and superbly determined people.

I wish to thank her Majesty the Queen for her gracious approval of my appointment.

I wish to express my gratefulness to the President and Governors of the "Stichting Eindhovens Hogeschoolfonds" for my appointment.

I wish to express my appreciation to the Board of Trustees who have recommended the Foundation's decision.

I wish to express to the members of the Senate the happiness and the pride with which I shall try to participate in their great endeavor.

I wish to thank the members of the Department of Chemistry for their warm welcome.

I wish to thank Professor KEULEMANS for his kindness in inviting me to be one of you.

I am looking forward to the formal courses I shall give, and to the seminars in which I shall try to indicate to my students the importance of leaving no pertinent stone unturned in their research, for under one of them lies the key of the discovery or invention it may be their privilege to make.

Ik dank U voor Uw aandacht.