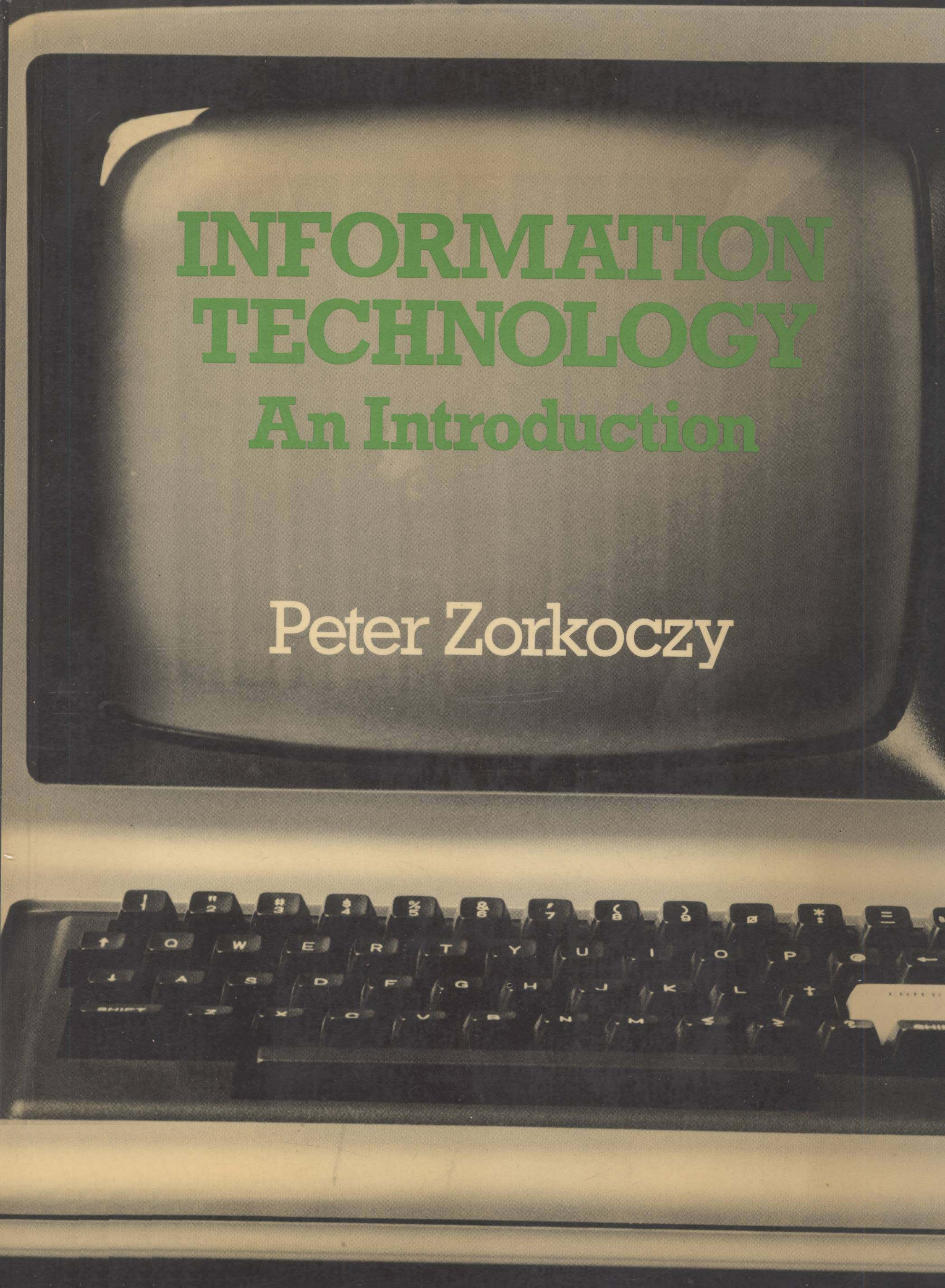
INFORMATION TECHNOLOGY

An Introduction

Peter Zorkoczy



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Preface

This book is intended as an introduction to the current concepts, applications and tools of information technology. It is for the non-specialist in the field and does not assume a familiarity with the underlying mathematical and engineering ideas. The book is organized into two main parts; these are graded in their level of technical detail. In Part 1, Chapter 1 is about some of the fundamental concepts of information technology, in particular about information itself. Chapter 2 is about the applications of this new technology in many areas of industry, commerce, education and training, leisure, medicine and welfare. Established applications are clearly distinguished from those which, though technically feasible now, are possibilities for the future.

These two chapters are essentially descriptive in their approach. They aim to explain more *what* information technology can do, rather than *how* it is done. That latter job is reserved for Part 2. There, the important concepts and tools of information technology are given a more technical treatment, though still at an introductory level.

Part 2 includes a résumé of the three areas which form the historical basis of information technology: *computers*, *telecommunications* and *data networks*. A further ten chapters are devoted to the relevant technical developments which have grown out of the first three over the last few years, ranging from 'artificial intelligence' to videotex systems.

Readers who wish only to gain an impression of the scope and implications of information technology will find the first two chapters adequate for this purpose, and could use Part 2 and the general reading section as reference sources. Such readers will welcome the generous cross-referencing from Part 1 to Part 2. Readers with an interest in, but no background knowledge of, the technical aspects of information technology may find it helpful to read about computers and telecommunication systems in Part 2 first, as these form the foundation of the subject.

When writing this book I have been keenly aware that information technology is in a period of dynamic growth, accompanied by all the growing pains and uncertainties which characterize the 'adolescent phase' of a young subject. What I aimed to do, therefore, is to set out the 'family tree' of information technology, and to provide a 'snapshot' of the face it presents at the time of writing. By the time this book reaches its readers the face will have matured, but I hope the highlighted features will remain recognizable.

Peter Zorkoczy
February 1981

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Part 1

1 About information technology

What's in a name?

'Information technology' is a relatively recent and perhaps not particularly well-chosen addition to the English language. It has its counterparts in the French 'informatique' and the Russian 'informatika'. For many people, 'information technology' is synonymous with 'the new technology'—the use of microprocessor-based machines: microcomputers, automated equipment, word processors and the like. But the use of man-made tools for the collection, generation, communication, recording, re-arrangement and exploitation of information goes back in time much beyond the present 'micro-revolution'. For others, the significance of the introduction of a new term, 'information technology', is the belief that the principles, practice and terminology of information handling can be treated on a unified, systematic basis. Cynics may say that the words 'information technology' simply represent an attempt to make respectable some commercially motivated developments in electronics, and politically motivated moves to control the access to information.

Whatever is the truth behind these attitudes, to qualify as a 'technology', in the sense of being 'a practice of an applied science' (*Oxford English Dictionary*), there has to be a recognized science of information. Of course, the words 'information science' have been used, and are being used, to refer to a branch of librarianship dealing with the automatic retrieval of printed documents. But to rely purely on this aspect of information handling for parentage would be too restrictive for this infant field of technology. More properly, one must look towards the science of electronic systems and to computer science to legitimize the products of their convergence.

Even these sciences have their sceptics and it will be only when the science of information reaches a maturity of its own that one can use the name 'information technology' in any more than a loose way. We shall, therefore, not formulate a precise definition at this stage, but rather attempt to illustrate by examples, and describe in terms of constituent parts, the subject that is currently taking shape under the umbrella term of 'information technology'.

The motivating forces

There is a number of reasons why information technology is becoming a subject of wide-ranging discussion and study. Each of these reasons is significant on its own, but by acting together, as they are doing at the present time, they are adding urgency to the need to understand the technical and social issues involved. From a *social* point of view, information technology promises changes in the way we communicate and reach decisions. Even in its era before the computer, progress in telecommunications—for example, telephone, radio and television—

opened out the horizons for individuals and society at large, and so placed at the disposal of people information about distant events and new ideas. This has helped us to understand some of the complexities of the surrounding world, but has in turn increased that complexity by making possible a greater degree of interaction among people.

The application of the computer to information handling has contributed a new tool and a new dimension of complexity, through its ability to store and process vast amounts of data at high speed. For many decades now, data gathering devices (e.g. measuring instruments) have increasingly extended the accessible portion of the physical world and added to the already vast stock of scientific and technical information. Improved technological tools for collecting data about people have encouraged administrative applications of information technology. However, the cost and complexity of these tools have made them the virtual monopoly of the state and of large commercial enterprises. This created a potentially threatening opportunity for highly centralized control and decision-making. Recent technological developments in microelectronics have somewhat changed this situation by reducing the price of some data handling tools and making them more widely available. But has the danger of information technology being used for increased control of peoples' lives been averted completely? The answer can be gained only through better understanding of the technology and its implications.

In parallel with the growth of information resources, there has been a significant social change: a shift in the profile of the working population towards information-related jobs. In the United Kingdom, for example, one in every three people employed in the manufacturing industries is classified as an 'administrative, technical or clerical worker', as opposed to one in every four in 1965. Table 1.1 shows the breakdown of the 11.2 million people employed in information-related industries in the UK in 1978 (out of a total working population of 22.7 million); the underlying trends are shown in Fig. 1.1.

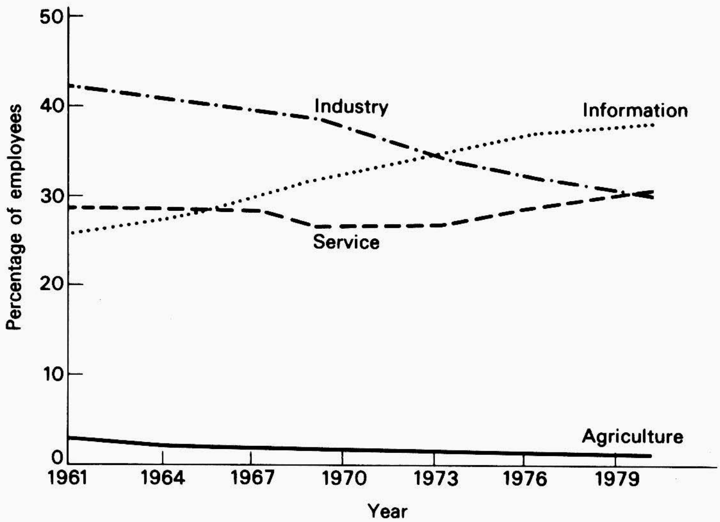

Fig. 1.1 **Changes in the percentage of employees in various sectors of the economy of the United Kingdom. The information sector includes public administration, administrative, technical and clerical workers in the manufacturing industries, professional and scientific services, insurance, banking and finance. The service sector includes distributive trades, transport and communication and miscellaneous services. (Source: Department of Employment)**

Table 1.1 **Employment in information-related sectors in the United Kingdom 1961–1978 (Source: Department of Employment)**

	Number employed (millions) 1961	1978
Administrative, technical and clerical staff in manufacturing industry	2.00	2.03
Distributive trades	2.76	2.74
Public administration	1.40	1.63
Insurance, banking, finance	0.68	1.15
Professional and scientific services (education, health care, communication, etc.)	2.12	3.68
Totals	8.96	11.23
Percentage of labour force (not including self-employed and the armed forces)	40.20	49.40

Note that these figures relate to employer classification, rather than employee, or occupational groups. There are no figures being issued for the latter in the United Kingdom.

In the United States, the trends are similar, as indicated by Fig. 1.2. Note that, by about 1960, more people were engaged in the handling of information than in producing food, manufacturing goods or providing services. The breakdown of the information-sector occupations (see Fig. 1.3*) indicates how the steady increase in the number of professional and technical workers, on the one hand, and managers and administrators, on

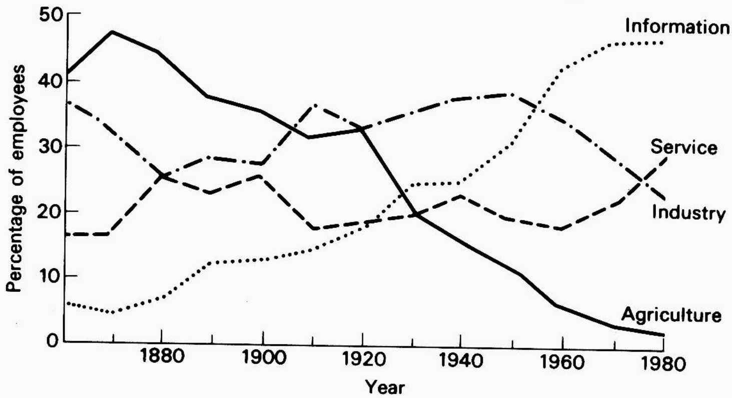

Fig. 1.2 **Changes in the percentage of employees in various sectors of the economy of the United States. The information and service sectors are defined as in Fig. 1.1. (Source: US Bureau of Labor Statistics)**

the other, has been accompanied by an increase in the number of their support staff—the clerical workers. Such social trends are not easily reversed, and there is no reason to believe that the information sector will lose its dominant position in the employment field. Information technology, then, will have a direct impact on the majority of the working population of highly developed countries.

* This occupational breakdown was first suggested by Marc Porat in *The Information Economy*, US Government Printing Office, 1977.

From an *economic* viewpoint, the data in Table 1.1 and Figs 1.1 and 1.2 indicate a growing imbalance between traditionally 'wealth-producing' and 'overhead' occupations. At the present time, information handling is highly labour-intensive, and information workers command substantial remuneration. Yet, the value of the output of such workers is difficult to measure. How does one compare the 'output' of a teacher or a researcher with that of, say, a production-line operative?

In the absence of reliable measures of relative productivities, the traditional response of employers is to attempt to 'balance the books' in economic terms, by limiting overhead expenditures. As the most important component of this is labour costs, industry and government are turning towards information technology as a possible means of expenditure control. After all, it is argued, technology has a reasonable record in automating some production tasks; should it not be able to do the same in information handling?

What is the true cost of information? What is its market value? How does it fit into the present framework of economic decision-making? Attempts to provide answers to questions of this type furnish the second source of incentives to study information technology.

The third stimulus comes from the industries which have recently grown up around information-related products, in particular in

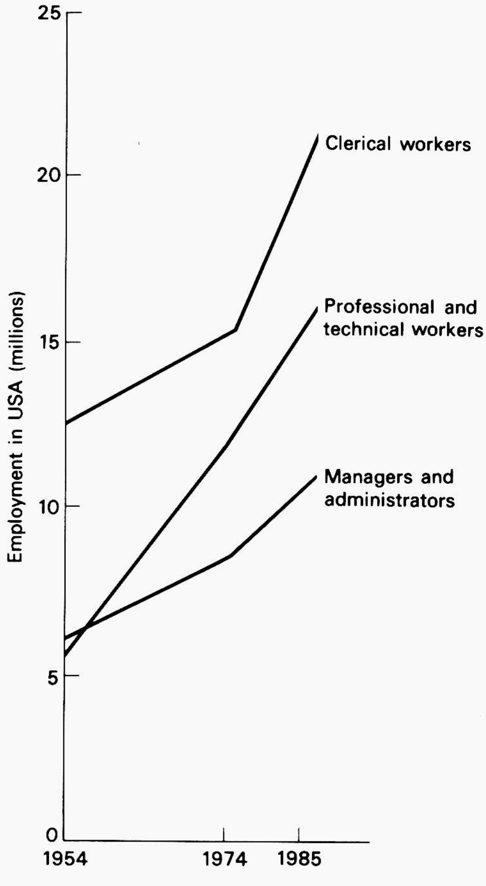

Fig. 1.3 Breakdown of the information-sector occupations in the United States, projected to 1985. (Source: *Monthly Labor Review*)

microelectronics. Manufacturers already active in the computer and telecommunication fields—the corner-stones of information technology—have now been joined by the silicon-chip industry in an attempt to open up new markets for their products: the office, the school, the publishing industry—the very places where information is in the forefront of interest. These manufacturers can be expected to turn out a vast range of products aimed at the population at large. But, to a large extent, the rapid progress in microelectronics caught the 'traditional' computer world unprepared for the greatly increased range of potential applications of its products. The engineering know-how is there, but it is still very much visible behind the thinly spread expertise on where and how to apply information technology, so that its *users* derive maximum benefit. In other words, at the present time, information technology is very much technology-led. Both the manufacturers and their customers require urgent answers to questions about the appropriateness and timeliness of various products. Such questions can be properly treated only by developing a better understanding of how the technology can complement human information handling.

Lastly, from the viewpoint of the *individual*, the possession and accessibility of information are becoming matters of personal importance. In societies made information-aware by computerization, communication technology, and shifting job patterns, the possession of information is increasingly seen as a key to professional advancement. So the control of access to information could, even more than before, become an expression of power, a weapon to be used by, or against, the individual. The growth of information technology has already given rise to concern about diminished individual freedom (see, for example, Carlson in *Information Technology Serving Society*, Pergamon, 1979). At the same time, it is placing at the individual's disposal vast resources of information, and more accessible means of voicing an informed opinion.

So, will information technology be, and be seen to be, a means towards the greater, rather than the more restricted, freedom of the individual? No answer to this question is possible without a better understanding of the technical and social issues involved and without an informed public discussion of the alternative courses of progress.

Seen from these four viewpoints—those of society, economics, technology and the individual first—the common element of information technology is the concept of *information*.

What is information?

People have a surprising range of ideas on what information is. (Just try asking a few people to define it.) Even dictionaries cannot agree. The *Oxford English Dictionary* gives it as 'that of which one is apprised or told; intelligence, news'. Another dictionary simply equates it to knowledge: 'that which is known'. Yet other definitions emphasize the knowledge *transfer* aspect of information, calling it 'the communication of instructive knowledge', or 'the knowledge conveyed to the mind by a statement of fact'.

The cause of this diversity in the common usage of the term is that information is essentially intangible: we encounter it only operationally, through its subjective effects. We *derive* information from data—from observations of the world around us. We *convey* information by communication.

'Information is the *meaning* that a human expresses by, or extracts from, representations of facts and ideas, by means of the known conventions of the representations used' (*Guide to Concepts and Terms in Data Processing*, North Holland, 1971). This is in many ways an attractive definition, but it includes the word 'meaning', which is just as intangible and elusive as 'information' (see, for example, Ogden and Richards, *The Meaning of Meaning*, Routledge & Kegan Paul, 1949). An important point, to which the last definition calls our attention, is 'the known conventions of the representations used'. When the representation is a language, as it frequently is, the syntax and the semantics of the language form an assumed supporting structure for any information expressed through it. For example, if we hear someone say, 'It is ninety-five in the shade', we can take this to mean that he is talking about temperature, that his numbers refer to degrees Fahrenheit, that the shade is not of any specific object, i.e. the temperature reading does not necessarily refer to only one place, etc. Consequently, by assuming that he employs the known conventions of the English language and culture, we can derive more information than was directly communicated by the original sentence.

The semantic and syntactic aspects of information occupy the attention of many linguists (see, for example, Bar-Hillel, *Language and Information*, Addison-Wesley, 1964), but have so far not led to a generally accepted definition of information. 'Information in most, if not all, of its connotations seems to rest upon the notion of *selection power*', Cherry tells us in his thought provoking book *On Human Communication* (Science Editions, 1961). For example, we may think of a telephone directory as containing a great deal of information because each entry selects one person or organization out of a very large number in the geographical area covered by the directory. It also links that person with a unique selection of digits (the telephone number) out of the millions of possible combinations of those digits. Moreover, the directory repeats this selection process for all the subscribers listed. The postal address given for a subscriber is also an example of the selective power of information. The address is located by a process of increasing refinement: area, town, street, house, etc.

Note that behind the selective aspect of information is the assumption of the existence of a finite, albeit large, number of alternatives which are known to *both* the originator and the user of that information. (Otherwise, the process is no longer that of selection.) Thus, in the case of names in a telephone directory, the possible alternatives are the various ways in which the letters of the alphabet can be combined. But the universe of knowables—concepts, ideas, facts, names, etc.—is practically *infinite*. This apparent impasse between what we may want to communicate and the way we communicate is resolved by separating the *content* of information from its *representation*.

The representation (symbols, signs, signals, etc.) can then indeed belong to a well-defined finite set (the alphabet, dots and dashes, etc.). The process of communication of information in that case becomes a process of communication of representations. New ideas will be communicated by new combinations of old signs. It is this totally objective way of looking at information transfer that is of interest to telecommunication engineers (and theoreticians), and lies at the basis of *information theory* (Hartley, 'The transmission of information', *Bell System Technical Journal*, 1928, p. 535; Shannon and Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, 1949).

The quantity of information

Information theory quantifies information (more exactly, the signs carrying a message) as follows: it assumes that the more unpredictable the message (i.e. the sequence of signs) generated by a source, the more information is being transmitted. Information then is described in terms of the statistical rarity of signs, and their combinations, produced by a source. The recipient is assumed to be aware of the relative probability of occurrence of each sign, and of combinations of signs; the information simply directs the recipient to select one of these combinations—the selection process again. Note that by allowing for a prior knowledge of the probability of combinations, the theory includes an important characteristic of practical languages: redundancy. Redundancy, that is superfluousness, does not add to information, in this sense. It helps, however, in the detection and correction of errors which may occur during the transmission of the message.

Messages are transmitted by superimposing the signs on some form of physical medium—a carrier. The carrier may be paper, electromagnetic waves, magnetic tape, etc. Every carrier has associated with it a (theoretically) quantifiable limit of the amount of signs it can accommodate per unit space or unit time, and also of the amount of distortion it is likely to introduce into messages. Information theory tells us how to estimate these limits and, more importantly, how to represent (encode) messages so that when they are transmitted via a given carrier, the decoded message contains a minimum of errors.

By guiding telecommunication engineers towards achieving the accurate transmission of messages, information theory remains to this day a corner-stone of engineering practice. But, of course, accurate transmission of inaccurate information does not make that information any 'better'. The communication engineer does not, as a rule, concern himself with the content, or 'quality', of the information. The words 'better' and 'quality' reintroduce the element of subjective judgment into our notion of information, which we again consider to be the *combination of content and representation*. So let us look at some of the factors which may affect the quality of information in this wider sense.

The quality of information

We all expect information to be *reliable* and *accurate*. In other words, information should be in agreement with reality. The trustworthiness of information is increased if it can be *verified*, that is, corroborated by independent means. Information must be sufficiently *up-to-date* for the purpose that it is to be used. It must be *complete* and *precise*, allowing the recipient to select specific details according to need. If incomplete, the degree of uncertainty must be indicated, or else it should follow some