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AN HISTORICAL PERSPECTIVE OF MASS STORAGE

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ABSTRACT

The need to store information is older than civilization itself. Primitive peoples recorded information about their lives, activities, and environment as early as the Paleolithic Era, and some of these records are still extant. Beginning with these records, this paper will revi some of the symbolisms, media, and tools use recording information through the major ages of technology, with emphasis on the very early history of the recording of information.

INTRODUCTION

Information is only as valuable as it is accessible, and mass-storage systems contribute to the value of information by providing repositories for information and making information accessible on demand. Ideally, all human knowledge would be stored on line and be immediately and interactively accessible to all human beings having a need and a right to know. However, we are very far from that ideal, so there is a great deal of work left to do in the development of mass-storage systems.

Regardless of the technologies used, the recording of information requires three things: a symbolism with which to encode the information, a medium on which to record the symbolism, and a tool to record the symbolism on the medium. For example, the earliest recorded information used talley marks as the symbolism, bone for the medium, and a cutting implement to record the talley marks on the bone. A modern disk unit uses binary magnetic states as the symbolism, a magnetic surface to record the information, and a recording head to create the magnetic states on the medium. In spite of the differences in these technologies, the three requirements for the recording of information are met in each instance.

The purpose of this paper is to review the history of the technologies used for the storage of information, where "the storage of information" will be interpreted in the generic sense rather than limited to electronic computers. As such, this history overlaps the histories of writing, mathematics, computing, and automatic control. At present, there are three main types of repositories for human knowledge: the human memory, printed matter, and machine-accessible storage. It is beyond the scope of this paper to review human memory, but we will review the histories of the other two types of mass-storage systems, emphasizing the recording of information using artifacts. We will also take note of some of the highlights of the history of mass storage using mechanical, electro-mechanical, an' electronic technologies.

RECORDING INFORMATION: ARTIFACTS

Although we do not normally think of them as such, books and libraries are mass-storage systems. Indeed, through most of human history they provided the only mass-storage systems. Thus, it is appropriate to review the history of the symbolisms, media, and tools used in writing and printing in our review of the history of mass storage.

Prehistoric records. The term "artifact" is used here to refer to an object made by humans but limited to objects that are not machines, i.e., do not transmit force or energy. The earliest artifacts known to record information come from the Upper Paleolithic Era, the era just before 10,000 B.C. Alexander Marshack's study, The Roots of Civilizatio [1] documents a set of artifacts made of bone ar reindeer antler from the caves of southern France dating to the Paleolithic Era and perhaps even earlier. Marshack argues persuasively that some of these objects contain notations, some of them recording a primitive form of a calendar and others recording the number of animals killed by the tribe. That these people, whom we often think of as little more than animals themselves, should feel the need to record information and use it in the conduct of their lives is a little deflating to the modern ego. The "Age of Information," as some authors refer to the modern age, obviously has roots that lie very deep in human history. It is clear that the recording and use of information, which allows that information to transcend both time and space, is important in the conduct of human affairs, even in relatively simple cultures.

Precursors of writing. The events collectively known as the Agricultural Revolution occurred in the Near East about 8000 to 9000 B.C. when people began domesticating plants and animals and living in villages rather than depending strictly on hunting and gathering. It is in this era that we find the precursors of writing through studies in paleography (the history of written documents) and epigraphy (the history of inscriptions).

Recent studies indicate that the earliest precursors of writing were invented by the Sumerians, who used clay tokens of various shapes to convey information.[2,3] Tokens were used for both numeric and non-numeric information, including such mundane things as bread and beer, houses and horses, lions and dogs. These tokens were used for some 5000 years as discrete objects, eventually leading to the invention of writing using pictographs of the clay tokens as a symbolism impressed on clay tablets with a wedge-shaped (cuneiform) stylus. The invention of writing apparently quickly passed to the Egyptians, who by 3000 B.C. had developed their own form of writing called "hieroglyphics" (sacred carvings).

Evolution of alphabets. The symbolism of writing passed through several transitions, including:

- pictographs (pictures that represent the object intended),
- ideographs (abstract symbols of objects or concepts),
- logographs (symbols for spoken words),
- syllabaries (symbols for syllables),
- consonantal alphabets (symbols for individual consonantal sounds), and
- full alphabets (symbols expressing both consonants and vowels).

This is not to imply that there was a simple flow from one of these forms to the next; rather, several of them often coexisted even within a single symbol system--and still do.

The earliest pictographs are the invention of the Sumerians and date from the last centuries of the 4th millenium B.C.[2,6] In the following millenium, the use of ideographs and logographs spread throughout the Near East;[5,10] however, this form of writing has the disadvantage that a large number of symbols are required (several thousand), and this makes learning the system very difficult and inhibits its use. The more efficient use of syllabaries developed in the 2nd millenium B.C., and this reduced the required number of symbols to less than 200.

The first alphabet, in which some 20 to 30 separate symbols represented distinct sounds for the consonants, is referred to as the Proto-Semitic alphabet, which dates from about the 10th century B.C. A Southern-Semitic form of this alphabet led to the development of the Ethiopic and Arabic alphabets that are still in use. The Northern-Semitic alphabet had two branches, the Aramaic and the Canaanite. The Aramaic alphabet was the parent of alphabets used in India and Persia, as well as the square Hebrew alphabet currently in use. The Canaanite alphabet was the parent of the Phoenician alphabet and the early Hebrew alphabet (an earlier and different form than the square Hebrew). Through the extensive trade routes of the Phoenicians, their consonantal alphabet passed to many other cultures, including the Greeks who by about the 9th century B.C. had added explicit vowel symbols to the consonantal alphabet to create the first full alphabet.[15] The Greek alphabet was adopted by the Etruscans, a people who dominated Italy before the Romans, and whose alphabet was in turn adopted and modified by the Romans to form the Latin alphabet, which is the most widely used of the approximately 50 alphabets in use today.

The Chinese independently developed a method of writing using the so-called "oracle bones," the earliest examples of which come from the Shang Dynasty of about 1500 B.C.[18] Bones were scored and then heated, and the resulting cracks in the bones were interpreted as a forecast of the future, which was then written on the bone. The Shang symbols are relatively sophisticated and must have had a long history before the Shang Dynasty, but the details of their development are not yet known. The earliest symbols found in China come from the Yang-Shao culture of 5000 B.C. in the form of pottery marks that bear some resemblance to the later Shang symbols.[11] Curiously, in spite of their long cultural histories, neither China nor Japan uses an alphabet even today, using instead the Kangi symbolism, which is a mixture of pictographs, ideographs, and phonetic symbols.[16] In addition to Kangi, Japan also uses the Katakana and Hiragana syllable systems.

The lack of an alphabet probably hindered the development and spread of Chinese and Japanese learning. The Chinese had developed both paper and simple forms of printing by the 2nd century A.D. and had wooden type by the 6th century A.D.[19] The earliest known printed works come from Japan about 764-770 A.D., and the earliest book comes from China about 868 A.D. A set of 130 volumes of Chinese classics dates from 932 A.D., constituting the first known library of printed books. However, the large number of symbols (tens of thousands) required for Kangi writing inhibited the preparation of originals that could be copied with printing. The European countries did not have both papermaking and the tools and techniques for printing until about the 15th century. Yet it was from Europe, where paper and printing were combined with the efficiency of the Latin alphabet, that the printing press was used to provide low-cost books and to spread literacy and learning worldwide.

Number systems. As symbolisms for expressing numerical information, number systems have played an important role in the recording of information. The four basic types of number systems include the following:[22]

- Additive number systems add symbols to create larger units. The Egyptians, for example, used an additive number system with individual symbols for units, tens, hundreds, etc., and merely added the appropriate number of symbols of each type to indicate the number wanted. Roman numerals are also an example of an additive number system.

- Cyphered number systems use the first nine letters to designate the units 1 through 9, the next nine letters to designate the multiples of 10, and the next nine letters to designate the multiples of 100s. For example, the Greeks used their alphabet for both numeric and non-numeric symbols.[21] Cyphered number systems require fewer symbols than do additive number systems, but they are difficult to use in numerical operations.

- Multiplicative number systems use a combination of units with multiples of a base. For example, the Chinese and Japanese still use a multiplicative number system, with a number like 4257 being expressed as 4 x 1000 + 2 x 100 + 5 x 10 + 7.

- Positional number systems are a logical extension of multiplicative number systems, but with only the coefficients being expressed and the orders of magnitude being understood. Positional number systems were used by the Babylonians (but without an operational zero)[21] and later by the Arabs before the introduction of this notation into Europe in the Middle Ages. Positional number systems were also used by the Mayas and Incas in the Americas.[7,8,12]

The quipu, used by both the Chinese and the Incas, provides an interesting example of a recording system.[7,20] The symbolism consists of knots tied in strings, with different knot shapes designating different units, and the position of the knots on the string specifying the magnitude.

Although base-10 number systems have been the predominant number systems used in the past, and still are for human use, the binary number system may well record more total information in modern times than base-10 number systems.

RECORDING INFORMATION: MECHANICAL DEVICES

We do not normally think of mechanical devices as storing information, but any machine carries in its mechanism the information that specifies how it will operate. For example, a clock has in the number of teeth in its gears the information that determines how it will operate. Thus, the recording of information and the design of control mechanisms are closely related.[21] When machines were first invented, their operations were fixed at the time of their design.

Variable-function mechanisms, in which input information determines the mode of operation, began with programmed weaving. Programmed weaving was invented in France in the early 18th century, first through the use of punched holes on a band of paper (Bouchon, 1725) and shortly thereafter with punched holes on cards (Falcon, 1728).[24] This was an important advance in control mechanisms because it allowed a machine to do different things depending on its input, rather than having its operation fixed when it was designed.

The punched card was adopted for the storage of information and for control in computation by Charles Babbage, an English mathematician, and this medium dominated information storage for almost two centuries.[14]

The calculating devices of the mechanical era were designed primarily for processing rather than storing information. The Babbage design (never completed) was an exception; it included a "store" having a capacity of 1000 words of 50 decimal digits each and provision for off-line storage of data on punched cards.

The mechanical printing press, the punched card, and the mechanical typewriter were the dominant mechanical technologies used for recording information until supplanted by electromechanical methods.

RECORDING INFORMATION: ELECTROMECHANICAL DEVICES

The electromechanical punched-card accounting machines invented by Herman Hollerith, a statistician from Buffalo, New York, for the American census of 1890 were the precursors of a generation of machines that greatly expanded the ability of business and government to store and process information. He invented keypunches, gang-punches, tabulators, and sorters which significantly improved the capacity and accessibility of mass storage systems. Hollerith's company eventually became the International Business Machines Corporation. A competitor of Hollerith's, James Powers, invented the punched-card machines used in the American census of 1910; the Powers' company merged with several others in the 1920s to form Remington-Rand Corporation. Electromechanical punched-card methods dominated information storage through the decade of the 1940s, and were used even after the invention of electronic computers. Although they are still in use today, they have a minor role as compared to the past.

RECORDING INFORMATION: ELECTRONIC DEVICES

The first electronic computer, the ENIAC, was developed at the Moore School of Electrical Engineering of the University of Pennsylvania; it was publicly demonstrated in 1946. Interestingly, this very first electronic computer used a storage hierarchy:

- 20 adding and storage registers provided high-speed electronic storage of information;
- 312 words of storage were provided in a set of "function tables" which were initially intended for storing tables of transcendental functions, but later used for read-only program control; and
- punched cards were used for mass storage.

The electronic storage hierarchy has evolved during the 30-odd years since the ENIAC through the use of magnetic cores, semiconductors, magnetic tapes, magnetic drums, magnetic disks, and optical recording devices, but the hierarchical storage concept is still an essential part of computer architecture.

CONCLUSION

Mass storage allows us to transcend many of the limitations of space and time in the recording and use of information. The technology of mass storage has changed dramatically over the past several thousand years, but modern methods are the direct descendants of the methods used by our ancestors. In fact, the archival quality of ancient mass storage systems is probably superior to anything in use in electronic computers today.

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