

Coding for Error Control in a Computer-manufacturer's Environment: A Foreword

"... before the computer truly enlarges the citizen's world ... I think that first of all we have to change the way we do software. ... We must make it possible for everyone to communicate with a computer. ... We must also increase [the computer's] reliability and think of computers not as machines in the basement but as devices that provide a service to a community and cannot fail. Let me assure you that this is an important change in the framework of mind of today's designers and manufacturers. We must achieve reliabilities that are unknown to computers today, but are feasible. ..."

The above statement was made in an address to the 1969 IEEE International Convention by Dr. Eugene Fubini. The point is unmistakably clear. Aside from the universally acknowledged software problem, reliability is considered the next most important concern for the designer and manufacturer of computer systems. It is therefore most appropriate that the *IBM Journal of Research and Development* should at this time devote an issue to topics in coding theory with emphasis on its application and usefulness to the improvement of reliability of computer systems.

Historically, IBM has always been a pioneer in the development and adaptation of current coding techniques to computer systems; its effort dates back to the use of the parity check on the punched card. The parity was followed by the wide use of the vertical redundancy check (VRC) and the longitudinal redundancy check (LRC) on magnetic tapes. More recently, cyclic redundancy checks (CRC) have been used for error detection in various storage systems and for binary synchronous communication (BSC) line control.

Error correction with a Hamming code was adopted for the IBM 7030 system, while a 2-adjacent error correction scheme was used for the Hypertape system. Codes capable of correcting large number of errors are used in the System/360 800-bit-per-inch tape system and the Photo Digital Storage System.

Error correcting codes are assuming more importance in computer systems today because of several recent developments in computer technology and usage, namely, 1) the increasing speed of computation and greater packing to density which narrow the margin on signal-to-noise ratio; 2) the economical advantage of a usable but imperfect device, especially with LSI technology, and 3) the increasing emphasis on communication-based computer systems.

The papers in this issue reflect the current needs and emphasis, and can be roughly classified into three

groups. The first group of papers is concerned primarily with the use of codes in storage reliability improvement. The paper by Brown and Sellers presents the error correction scheme used in the System/360 800-bit-per-inch magnetic tape. This code is capable of correcting error bursts of unlimited length in any one of the nine tape tracks. The paper by Hsiao discusses a new class of single-error-correction and double-error-detection codes that is optimum among codes of that type in performance, cost and reliability. Newly proposed codes include the *b*-adjacent codes by Bossen, which feature cluster correction, and the orthogonal Latin square codes by Hsiao, Bossen and Chien, which offer high-speed decoding procedures.

The second group of papers is concerned with novel uses of coding concepts in storage, transmission and terminals. A new coding approach to magnetic recording is proposed by Kobayashi and Tang. In their paper the magnetic recording process is viewed as a precoding of a partial-response channel. A new high-density recording method, "interleaved NRZI", is suggested. Related error detection methods with minimum delay are also discussed. A related paper by Franaszek discusses new sequence-state methods for run-length-limited coding. These methods are useful primarily for increasing the density of recording channels. The paper by Tang and Lum proposes error control schemes for human operator errors at computer terminals. Consideration is given to the transpositions of adjacent symbols and to substitution, deletions and insertions. The remaining two papers in this group are concerned with improving data transmission characteristics. Kobayashi considers coding schemes for the reduction of intersymbol interference in pulse amplitude modulation systems. Croisier considers many of the pseudoternary codes used in data transmission for controlling the power distribution in the frequency spectrum, improving clock recovery, allowing error detection or increasing the data rate.

The final group of papers deals with important questions in basic coding theory. Savage suggests three measures for decoder complexity. This study is clearly aimed at a thorough understanding of the decoding process and its implementation limitations. The paper by Patel describes a number of interesting new results in maximal group codes. This study is useful in understanding codes of higher redundancy and their bounds on efficiency. Finally, a study of the performance of codes is described by Rocher and Pickholtz. Here an interesting performance comparison is made among pure retransmission, forward-error-correction and hybrid schemes.

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