NASA TECH BRIEF
NASA Pasadena Office

Low-Cost Coding Techniques for Digital Fault Diagnosis

Diagnostic programs are used at the present time to detect errors in the operation of digital computers; the normal operation of the computer is interrupted periodically, or when an error has been sensed, and a diagnostic program is put into play to check the functioning of each logic circuit. Special-purpose hardware is included in contemporary computer systems in order to facilitate error detection and the application of diagnostic programs.

An alternative approach to fault diagnosis is to use codes which can detect and correct errors. Encoded data words (using parity, Hamming, residue, and some other codes) are common in digital systems; the codes quite frequently are the sole means for error detection in computers. Recently, error-detecting codes have been employed to encode the instruction words as well as the data words of an experimental computer; the most common use of these error codes is for the transfer of data within the computer. An error-correcting code will identify the bit index (or indices) i of the altered bits and thus locate the fault to a bit-position in the logic which delivered the incorrect word; thereafter, the faulty logic package is replaced, or the computer can be programmed to abbreviate subsequent activity within an operational routine. The error code must be preserved during arithmetic if the arithmetic operation as well as data transfers are to be validated, and the class of applicable codes is thus limited to arithmetic codes.

A study has been made of digital fault diagnosis using arithmetical coding techniques and a report has been published which discusses fault location properties of arithmetic codes.

The usual criterion for the effectiveness of a given arithmetical code is the guaranteed detection of weight-1, weight-2, and weight-3 error magnitudes; this criterion is generally used in transmission codes. A more general criterion, which includes an algorithmic arithmetic processor, is the probability of detection of a local fault by the application of the checking algorithm to the results of the entire set of algorithms of the processor. The second criterion, which is essential in the choice of an arithmetical code, is the total cost of checking (time and hardware), and this depends on two factors:

(1) The compatibility of the code with the algorithms of the processor.
(2) The direct cost of the checking algorithm.

It is evident that a practical checking method must be acceptable from the viewpoints of both cost and effectiveness; simultaneous optimization is an interesting objective. For radix-2 numbers, any odd integer $A>1$ will detect error magnitudes of weight 1. Values of A which provide detection of all error magnitudes of weights 2 and 3 and correction of weight 1 magnitudes within a limited range of X have been described, as well as values of A for burst-error and large-distance error detection and correction. The cost of checking and the detection of errors arising from repeated use of faulty circuits were not considered in these codes.

The report also presents an analysis of a class of arithmetic codes with a low-cost check algorithm which possesses partial fault-location properties. Complete fault location (i.e., single error correction) is then attained by multiple encodings. The results are applied to both residue and product (or An) arithmetic error codes.

(continued overleaf)

Note:

The following documentation may be obtained from:

National Technical Information Service
Springfield, Virginia 22151
Single document price $6.00
(or microfiche $0.95)
Reference:
JPL Technical Report 32-1476 (N70-35664), Digital Fault Diagnosis by Low-Cost Arithmetical Coding Techniques.

Patent status:

NASA has decided not to apply for a patent.

Source: Algirdas Avizienis of
Caltech/JPL
under contract to
NASA Pasadena Office
(NPO-11701)