One approach to fault dictionary size reduction

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Abstract

This paper describes an approach to reduction of a diagnostic information with a help of masks of fault dictionaries. The new algorithm for finding of a mask is proposed. The new algorithm has appropriate time characteristics and small memory requirements. The experimental results show an effectiveness of proposed algorithm on fault dictionaries of circuits in ISCAS'89 benchmark set.

Keywords: Diagnosis, fault dictionary, diagnostic information reduction.

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1 Introduction

Fault dictionaries are the most widely used technique for testing circuits. Precomputed fault dictionaries stores the signature of each fault under a fault model. Diagnosis using a fault dictionary compares a signature derived from the circuit under test to pre-stored ones. Pre-stored fault in the dictionary most similar to the considered one will be the final conclusion.

The simplest fault signature that can be obtained is a full response of circuit to a test set in the presence of the fault under a fault model. The *full response dictionary* is a fault dictionary that consists of such signatures.

The main objection to the usage of full response dictionaries consists of their extremely large size. Such dictionary can require Gbits of storage for today's integrated circuits.

But often dictionaries contain redundant information and can be made significantly smaller [1–5, 11, 12]. In order to reduce the space needed to store this data set, many techniques have been proposed.

Some of the techniques for dictionary size reduction is based on using of so-called "masks" [2, 6–9, 13–15], when fault dictionary stores "masked" fault reaction to the test sequence as a fault signature.

The mask for full response dictionary can be represented as a bit-vector, where each bit corresponds to the position of full reaction of circuit to the test sequence. Zero bits of the mask show the redundant positions of the full reaction. The output-compacted signature of a fault is the result of application of the mask to the full response of circuit to a test set in the presence of the fault under a fault model. It consists of values taken from the positions of full reaction corresponding to nonzero positions of the mask. Therefore, a number of nonzero bits in the mask is responsible for reduction of the fault dictionary size.

Diagnosis using a mask extracts a fault signature from full response of a circuit under test and compares it with pre-computed signatures in the fault dictionary.

Fault dictionary compression with use of mask may be essential in the other techniques of dictionary size reduction.

A *pass-fail dictionary* is a matrix where one bit of information per pair (fault, test vector) stored — a 1 if the circuit will fail the test in the presence of fault and 0 if it will pass. A diagnostic resolution of pass-fail dictionary may be worse than the diagnostic resolution of full response dictionary, but its size at least r times less than the size of full response dictionary, where r is the number of circuit primary outputs.

In practice the size of pass-fail dictionary can be reduced with the help of mask. In this case the records for each fault in pass-fail dictionary are used as the initial data for method of finding of a mask.

Pomeranz and Reddy's [11] proposed to use a greedy algorithm to choose columns from the full response dictionary to augment a pass-fail dictionary. The aim is to get *Compact dictionary* with little or no erosion of diagnostic resolution for the modelled faults. The mentioned greedy algorithm is, as the matter of fact, an algorithm of finding of a mask.

Arslan and Orailoglu [1] offered a method where test vector set partitioned into blocks and a fault dictionary stores a combined signature for each test vector partition instead of pass-fail information for each test vector. The second phase of this method consist of finding of a mask for the XORed pass-fail dictionary obtained after the first phase.

Boppana, Hartanto and Fuchs [3] proposed a dictionary organization where entry for each fault contain a delimited list of only faulty primary outputs for each test vector. Such dictionary can be more compact if it is created from a pre-found masked full-response dictionary, i. e. if it does not include excess faulty outputs.

The ideal mask provides a maximal reduction of a fault dictionary volume with the best diagnostic resolution. The problem of finding of such mask is NP hard and implies memory- and time-consuming computations.

Initial data for finding of a mask is fault dictionary (full response dictionary or pass-fail dictionary). Originally, for even moderate volume of fault dictionary the problem of finding a mask must be solved with the aid of suboptimal heuristic methods.

In this work we offer a new algorithm of this type. This algorithm, by definition, do not ensure that the result is optimal, but algorithm's result can be close enough to ideal. Moreover the timing data of algorithm and its memory requirements can be reckoned in advantage of its using.

2 Preliminaries

Further we are using following notations.

Consider a circuit with N modelled faults $\{f_1, f_2, \ldots, f_N\}$. Denote $F = \{f_i \mid 1 \leqslant i \leqslant N\}$. Let's the fault dictionary is the matrix $D = \|d_{ij}\|_{N\times M}$, where i-th row is a signature of i-th modelled fault.

Let R is the number of pairs of distinguishable rows in D and $P = N(N-1)/2$ is the total number of row pairs. We use the value R/P as the diagnostic resolution of fault dictionary D.

Any mask H for dictionary D is a bit-vector of length M. We define a volume of mask H as a number of its non-zero bits. The result of application of mask H to a D is a new fault dictionary D_H. Matrix D_H is received from a matrix D by removal of the columns corresponding to zero bits in mask H.

In general, we can state the problem of finding mask as following: for given fault dictionary D it is necessary to find mask H of minimal volume preserving the diagnostic resolution of D for D_H. In other words it is necessary to find such set of columns of matrix D, that provides the same number of pairs of distinguishable rows.

3 Algorithm

Each column of D partitions set of faults F into subsets according to values in this column. The collection of these subsets can be further partitioned by the other columns of D. If diagnostic resolution of D is equal to 1 then set F consequently partitioned by each columns of D will lead to singleton set.

In this terms, to find a mask of D means to find a subset of columns of D, that provide the same partitioning of F as D do.

To choose a columns for best partitioning we use the following ideas.

Let we have the set of faults $F' \subseteq F$ and $|F'|$ is the cardinality of F'. Then value

$$I(F') = \log_2 |F'| \tag{1}$$

indicates an average quantity of information needed for the identification of a fault from set F'. When F' is partitioned into $\{F'_1, \ldots, F'_{z_k}\}$ according to the values of k-th column the expression

$$I_k(F') = \sum_{j=1}^{z_k} \frac{|F'_j|}{|F'|} \cdot I(F'_j) \tag{2}$$

indicates the quantity of information needed for the identification after the partition.

Therefore, for the best partitioning it is necessary to choose a column which delivers the maximal information gain

$$G(k, F') = I(F') - I_k(F'). \tag{3}$$

As after the first partition of F we have a collection of sets it would be more preferably to choose such column of a matrix D which would deliver the best partitioning for the whole collection.

Let $\widetilde{F}$ is a collection of subsets of F. Then value

$$I'(\widetilde{F}) = \sum_{F' \in \widetilde{F}} \frac{|F'|}{|F|} \cdot I(F') \tag{4}$$

is an average quantity of information still needed for the identification of any fault from F. When collection $\widetilde{F}$ is partitioned according to the values of k-th column the value

$$I_k(\widetilde{F}) = \sum_{F' \in \widetilde{F}} \frac{|F'|}{|F|} \cdot I_k(F') \tag{5}$$

is the quantity of information needed for the identification after the partition.

In this terms for the best result it is necessary to choose a column which provides the maximal information gain

$$G'(k, \widetilde{F}) = I'(\widetilde{F}) - I'_k(\widetilde{F}). \tag{6}$$

If $\widetilde{F}$ consist of sets of undistinguishable faults then $G'(k, \widetilde{F}) = 0$ for any k. This fact may be accepted as a termination criteria for partitioning.

4 Experimental results

The proposed algorithm has been applied to fault dictionaries of circuits in ISCAS'89 benchmark set. For each benchmark circuit we created a maximal resolution full response dictionary for HITEC test vectors [10] and single stuck-at faults. We used PC with Celeron 1700 MHz processor and 256 MB of RAM.

5 Conclusion

In this paper one approach to fault dictionary reduction with the help of masks is proposed. A new algorithm for finding of a mask of a fault dictionary is presented. The given results show that the algorithm finds acceptable masks in short time and with small memory requirements.

The sets of experiments on the ISCAS'89 benchmark circuits demonstrate the significant dictionary reduction using masks found with the offered algorithm.

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