GENERALISATION OF THE TEST MODEL OF MULTIPROCESSOR SYSTEMS

Balázs POLGÁR
Advisor: Endre SELÉNYI

I. Introduction

The current paper presents an approach to the probabilistic diagnosis problem in multiprocessor systems using a generalised test model. The aim of generalising the test model is to handle the nine different test invalidation models uniformly and to neglect the 'perfect tester' assumption.
The main idea of the syndrome-decoding algorithm is based on the reformulation of the error propagation model as a Process Network Synthesis (PNS) model. PNS models are widely used in application fields related to chemical engineering to estimate optimal resource allocation and scheduling. However, the same mathematical paradigm can be used to model information flow in the same form as material flow. The paper illustrates this idea by formulating the maximum likelihood diagnostics in multiprocessor systems. The main advantages of the approach are generality, flexibility and extendibility of the modeling of test process.

II. Generalised Test Model

Multiprocessor systems consist of intelligent units being *good* or *faulty*. During diagnosis, they are testing each other and upon the set of test results (called *syndrome*) a central unit determines the state of each unit (this procedure is called *syndrome decoding*). In traditional approach a good tester was always perfect, that is its test result always corresponds to the state of the tested unit, while the behaviour of a faulty tester was determined by the nine possible test invalidation models, see *Table 1*.

Table 1
Possible test invalidation models

State of tester	State of UUT	Test result
good	*good*	0
good	*faulty*	1
faulty	*good*	$c \in \{0, 1, X\}$
faulty	*faulty*	$d \in \{0, 1, X\}$

Assigning probabilities to the *good* (0) and *faulty* (1) test results in each case, the test model can be generalised (*Table 2*). Since the good and faulty results are complementary events, the sum of the probabilities in each row is 1. In this model, for instance, p_{b1} can represent the fault coverage of the test or the probability of intermittent faults. Furthermore, the probabilities p_{c0} - p_{c1} and p_{d0} - p_{d1} give the possibility of a finer model than the 50-50 percent probabilities of the good and faulty test results in case of the value X for example in PMC test invalidation model (T_{XX}).

Table 2
Generalised test model

State of tester	State of UUT	Test result 0	Test result 1
good	*good*	p_{a0}	p_{a1}
good	*faulty*	p_{b0}	p_{b1}
faulty	*good*	p_{c0}	p_{c1}
faulty	*faulty*	p_{d0}	p_{d1}

All the nine traditional test invalidation models are special cases of the generalised model and can be determined by assigning *1* to p_{a0} and p_{b1}, *0* to p_{a1} and p_{b0} and according to *Fig. 1* to the other probabilities.

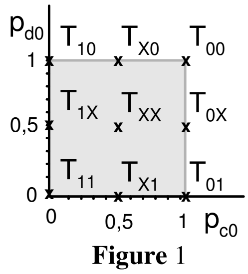
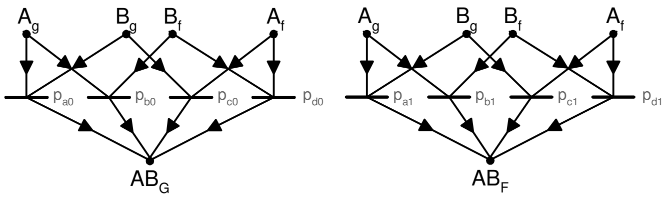


Figure 1

III. Syndrome Decoding in Generalised Test Model

In the literature the only approach similar to the above was Blount's *0-information tester* model, but his syndrome decoding algorithm was based on previously determined lookup tables. Formulating the generalised test model in the PNS-paradigm the most probable fault-pattern can be determined upon the syndrome without long, former calculations.
The adaptation of PNS algorithms is based on representing the states of units as raw materials, the

test results as products, and the elements of the test invalidation relation as operating units. Using the generalised test model *Fig. 2* shows the PNS model of a single test.



A_g – unit *A* is good; A_f – unit *A* is faulty; AB_G – *A* finds *B* to be good

Figure 2

The cost of each operating unit is defined to be the probability of generating the output material from its input materials, that is the probabilities associated to the rows of the test invalidation relation. The cost of a structure is the product of the probabilities belonging to the operating units in the structure, i.e. the occurrence probability of a syndrome in case of a fault pattern (assuming that the test results of the same unit are independent). Thus our objective is a syndrome decoding corresponding to maximum likelihood diagnosis.

Additional *constraints* on materials should also be defined in order to guarantee the consistency of the materials in solution structures, i.e. exclude structures containing both *good* and *faulty* states of a specific unit. Mathematically, $C_{A_G} \in \{0,1\}$, $C_{A_F} \in \{0,1\}$, such that $C_{A_G} + C_{A_F} = 1$.

This specific PNS problem can be solved either with a general program solving linear programming (LP) problems or with an adapted SSG algorithm generating combinatorially feasible process structures and determining the network with maximum likelihood.

IV. Simulation Results

For being able to compare results to previously existing probabilistic algorithms the PMC test invalidation model was used during simulation, although now the results are presented in themselves. Each value was calculated from 100 diagnostic rounds in two dimensional toroidal mesh topology with varying size (from *4x4* to *11x11*), containing faulty units of varying percentage (from *10%* to almost *100%*), and with each unit testing its four neighbours. During the simulation the model was formulated as an LP-problem and was solved by a commercial LP-solver, called CPLEX.

The measurement results (*Fig. 3*) show that the algorithm has more malign then benign mistakes (i.e. there are more misdiagnosed faulty then misdiagnosed good units), but in spite of this it has a good overall behaviour with respect to diagnostic accuracy if at least half of the processors are fault free.

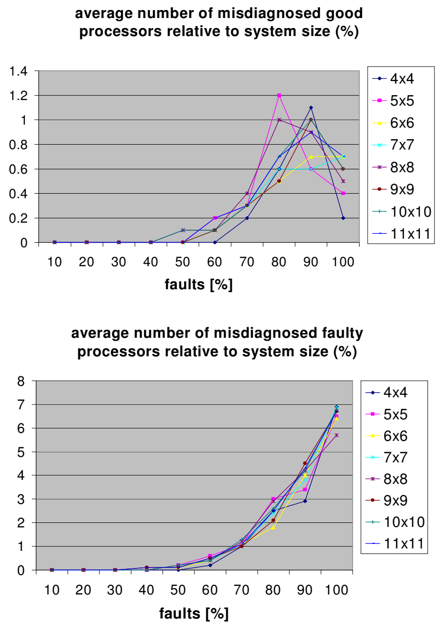


Figure 3

V. Conclusion and Future Work

The diagnostic accuracy of the decoding algorithm seemed to be encouraging especially at frequently occurring fault percentages. The other advantage of the generalised model formulated as a PNS-problem is its extendibility to handle permanent failure of a unit between two tests, to handle transient faults, and to diagnose upon multiple syndromes. The objectives of future work are extending the modeling these ways and determining the properties of the algorithm by further simulation and -if possible- by theoretical considerations.

References

[1] E. Selényi, „Generalised Theory of System-Level Diagnosis" *D.Sc thesis, Hungarian Academy of Sciences,* 1985. *in Hungarian*

[2] T. Bartha, „Efficient System-Level Fault Diagnosis of Large Multiprocessor Systems" Ph.D. thesis, BME-MIT, 2000.

[3] B. Polgár, Sz. Nováki, A. Pataricza, F. Friedler, „A Process-Graph Based Formulation of the Syndrome-Decoding Problem", *DDECS-2001, proc. of 4th Workshop on Design and Diagnostics of Electronic Circuits and Systems, p. 267-272, Hungary*, 2001.