Diagnosing Multiple Faults using Multiple Context Spaces

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ABSTRACT

Diagnostic problem solving is a major application area of knowledge-based system research. However, most of the current approaches, both heuristic and model-based, are designed to identify single faults, and do not generalize easily to multiple fault diagnosis without exhibiting exponential behavior in the amount of computation required. In this paper, we employ a decomposition approach based on system configuration to generate an efficient algorithm for multiple fault diagnosis. The basic idea of the algorithm is to reduce the inherent combinatorial explosion that occurs in generating multiple faults by partitioning the circuit into groups that correspond to output measurement points. Rules are developed for combining candidates from individual groups, and forming consistent sets of minimal candidates.

1. Introduction

The design of diagnostic systems is a major application area of knowledge-based system research. A number of successful diagnostic systems have been developed for medical, industrial, and engineering applications. The complexity of present day electronic and digital circuits and their use in large numbers has accelerated the need for automated fault diagnosis systems that are efficient and effective in real world applications. Most current approaches, both heuristic and model-based, are designed to identify single faults, and do not generalize easily to multiple fault diagnosis without exhibiting exponential behavior. An excellent introduction to different AI techniques used for diagnosis: associational (e.g., MYCIN[2]), functional (e.g., [9]) and structural (e.g., [3]) is presented by [12].
Recently a number of researchers ([3], [4], [10], and [14]) have proposed diagnosis systems based on model-based reasoning techniques as opposed to associational pattern matching techniques that link symptoms to potential causes [2]. They all view diagnosis as the process to determine the fault or faults responsible for an observed set of symptoms. Analysis by model-based reasoning techniques relies on generating behavior of a system from its structure and functionality derived from first principles.

Model-based approaches result in more general and robust techniques for diagnosis. Associational methods rely on the experience of human experts (source of associational knowledge), and, therefore, are mostly applicable in previously encountered situations (whereas model-based techniques are applicable to novel fault diagnosis). However, the methods proposed by [3] and [10] are effective only in single fault diagnosis. Davis represents the behavioral knowledge of the device as a constraint network, and dependency relations are established between output measurements, input data and components that influence the output measurement (pathways of causal interaction). A constraint suspension method is then applied to narrow down the set of candidates by relaxing constraints on individual component behavior (i.e., relaxing the constraint that describes correct behavior of a component), and propagating its effects to ensure that this relaxation does not contradict other measurements (to ensure global consistency). Note that this technique does not require the use of fault models, however, to apply it to multiple fault diagnosis would require applying constraint suspension to all possible combinations of components in a sequential manner. Similarly, Genesereth’s diagnosis scheme uses design knowledge to identify a suspect set. Design knowledge corresponds to the structural and behavioral knowledge of devices. The scheme then applies a traditional test generation method to generate the test set used to confirm and disconfirm the candidate components in the suspect set.

De Kleer and Williams [7] extended Davis’ work [3] and developed GDE (Generalized Diagnosis Engine), a general-purpose model-based approach for multiple fault diagnosis. They start off with a device model, which includes

- The device schematics-components that make up the circuit and their interconnections, and
- A behavior generating model-given a set of input values, the model can compute the correct (or expected) values at the output and other points at which measurements can be made.

Their diagnostic scheme, based on a two step approach: conflict recognition and candidate generation, is initiated when discrepancies are detected at measurement points. An assumption-based (ATMS) reasoning technique keeps track of multiple sets of consistent and inconsistent environments (possible faulty component sets). Rather than generate all possible candidates, their algorithm is made more efficient by generating only minimal sets of faulty candidates. They couple this mechanism with a probabilistic information theoretic scheme that defines an efficient probing strategy to help refine the candidate sets generated by the first step. [14] also presents a similar technique, but develops a more formal model based on a finite set of faults, symptoms, and causal connections between faults and symptoms. Recently there have been attempts by [15] and [6] to integrate fault models into model based diagnosis to further refine the candidate sets derived from the above analysis.

The primary motivation of this paper is that in real world circuit diagnosis, which involves MSI, LSI, and VLSI circuits, the complexity of the system being diagnosed is many orders of magnitude greater than the examples presented in above papers. It is not clear as to how well these algorithms would scale up when the complexity of the circuits to be diagnosed increases greatly in terms of the number of components