Preface

The semiconductor industry continues to relentlessly advance silicon technology scaling into the deep-submicron (DSM) era. High integration levels and structured design methods enable complex systems that can be manufactured in high volume. However, due to increasing integration densities and high operating speeds, subtle manifestation of defects leads to functional failures at the board level. Functional fault diagnosis is, therefore, necessary for board-level product qualification. However, ambiguous diagnosis results can lead to long debug times and wrong repair actions, which significantly increase repair cost and adversely impact yield.

A state-of-the-art diagnosis system involves several key components: (1) design of functional test programs, (2) collection of functional-failure syndromes, (3) building of the diagnosis engine, (4) isolation of root causes, and (5) evaluation of the diagnosis engine. Advances in each of these components can pave the way for a more effective diagnosis system, thus improving diagnosis accuracy and reducing diagnosis time. Machine-learning techniques offer an unprecedented opportunity to develop an automated and adaptive diagnosis system to increase diagnosis accuracy and speed.

This book provides a comprehensive set of characterization, prediction, optimization, evaluation, and evolution techniques for a diagnosis system. Readers with a background in electronics design or system engineering can use this book as a reference to derive insightful knowledge from data analysis and use this knowledge as guidance for designing reasoning-based diagnosis systems. Meanwhile, readers with a background in statistics or data analytics can use this book as a case study for adapting data mining and machine-learning techniques to electronic system design and diagnosis.

This book identifies the key challenges in reasoning-based board-level diagnosis system design, and presents machine-learning-based solutions and corresponding results that have emerged from cutting edge research in this domain. It broadly explores a series of topics ranging from high-accuracy fault isolation, adaptive fault isolation, diagnosis system robustness design, system performance analysis and evaluation, knowledge discovery, and knowledge transfer.

This book first describes a diagnosis system based on support-vector machine (SVM), multi-kernel SVM (MK-SVM), and incremental learning. The MK-SVM method leverages a linear combination of single kernels to achieve accurate root-cause isolation. The MK-SVMs thus generated also can be updated based on incremental learning. Furthermore, a data-fusion technique, namely majority-weighted voting, is used to leverage multiple learning techniques for diagnosis.

The diagnosis time is considerable for complex boards due to the large number of syndromes that must be used to ensure diagnostic accuracy. Syndrome collection and analysis are major bottlenecks in state-of-the-art diagnosis procedures. Therefore, this book describes an adaptive diagnosis method based on decision trees (DT). The number of syndromes required for diagnosis can be significantly reduced compared to the number of syndromes used for system training. Furthermore, an incremental version of DTs is used to facilitate online learning, so as to bridge the knowledge obtained at test-design stage with the knowledge gained during volume production.

This book also includes an evaluation and enhancement framework based on information theory for guiding diagnosis systems using syndrome and root-cause analysis. Syndrome analysis based on subset selection provides a representative set of syndromes. Root-cause analysis measures the discriminative ability of differentiating a given root cause from others. The metrics obtained from the proposed framework can provide guidelines for test redesign to enhance diagnosis. In addition, traditional diagnosis systems fail to provide appropriate repair suggestions when the diagnostic logs are fragmented and some syndromes are not available. The feature of handling missing syndromes based on imputation methods has therefore been added to the diagnosis system.

Finally, to tackle the bottleneck of data acquisition during the initial product ramp-up phase, a knowledge-discovery method and a knowledge-transfer method are proposed for enriching the training data set, thus facilitating board-level functional fault diagnosis.

In summary, this book targets the realization of an automated diagnosis system that offers the benefits of high accuracy, low diagnosis time, self-evaluation, self-learning, and ability of selective learning from other diagnosis systems. Although the goal of this work was to advance board-level diagnosis, the core techniques developed in this book can also be leveraged for electronic systems beyond the board level.

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