PROXELS FOR RELIABILITY ASSESSMENT OF FUTURE NANO-ARCHITECTURES

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ABSTRACT

As devices are scaled towards the infinitesimal, the occurrences of defects and failures will certainly increase. This is a statement that has been repeated on numerous occasions recently. Therefore, accurate evaluation of reliability should be considered—besides area, power, and delay—as one additional design parameter of future nano-circuits. The goal of this paper is to evaluate the applicability (for this particular task) of the recently developed proxel-based method. The paper will include a background on the proxel-based method, its customization for the particular task at hand, as well as experimental results regarding its applicability towards reliability evaluation of nano-circuits.

Index Terms— Nano-circuits, reliability, proxels, simulation, non-exponential distributions.

1. INTRODUCTION

As electronic devices are being scaled towards the infinitesimal, the frequencies of their defects and failures will simultaneously increase. This is a statement that has been repeated on numerous occasions recently (see e.g. [1]). Thus, accurate evaluation of reliability should be thoroughly considered (besides area, power, and delay), when designing nano-circuits.

The available reliability analysis methods (and tools) can be divided in two categories: *special-purpose* ones, dedicated to reliability modeling of nano-circuits, and *general* ones (see both an older review [2], as well as the very recent [3]). The special-purpose ones (such as RAMP [4] and PRISM [5]) can be quite expensive in terms of computation time and memory, or tend to oversimplify the models. This leads to approximate results and not always accurate conclusions about systems' behavior. Hence, a precise special-purpose reliability assessment method, which can deal with complex models in reasonably short computation times, would be very timely. The method should allow for a wide class of models to be analyzed by considering both types of errors that can appear.

The errors that occur in circuits can be either permanent or transient errors. Permanent errors occur either due to errors in the manufacturing process, or due to wear-out. Usually they are unrecoverable, and in some cases can lead to replacements of chips. Transient errors, on the other hand, are of temporal character, and the system typically recovers from them. They are also referred to as soft errors. A possible consequence of a soft error could be represented by an inversion of the value of a single bit (also known as von Neumann fault [6]). Our goal is to provide a method which would model both types of errors while assessing very accurately the reliability of systems with respect to both of them simultaneously. For this purpose we intend to make the most of the recently introduced proxel-based simulation method [7], [8].

2. THE PROXEL-BASED METHOD

The proxel-based method is a simulation technique based on the method of supplementary variables [9]. This is an alternative to the well-known discrete-event simulation. As shown in [10], failures that appear in nano-circuits cannot typically be modelled using exponential distributions. In fact, in [4], it was shown that the lognormal distribution is much more adequate for describing device failures, as opposed to the memoryless alternative, i.e., the exponential distribution (which has been in use for quite some time). For that reason, Markovian methods are not sufficient for accurate reliability analysis of future nano-circuits. Discrete-event simulation is often also not an option, as it tends to be very time-consuming. The proxel-based method, on the other hand, is very flexible and it can easily be applied to analyse models with transient errors, as well as errors that appear due to wear-out (see [7] for more details). The proxel-based method was applied successfully to simulation problems in the automotive industry [11], however, it was never used by the semiconductor industry.

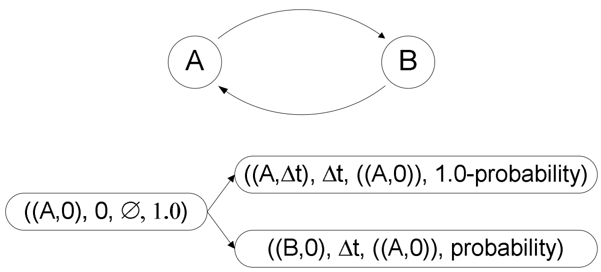

Figure 1. A two state model, and its two-level proxel-tree.

The proxel-based method advances by observing all possible developments of a model, probabilistically weighting each of them. At the end, a transient solution is obtained which contains the probability of each state at every point in time. The probabilities are calculated based on the instantaneous rate function (IRF). The IRF denotes the probability that an event will happen within a predetermined elementary time step, given that it has been pending for a certain amount of time (indicated as 'age intensity').

In Fig. 1, we present a basic two-state model and the first two levels of its proxel-tree. The latter one describes the advancement of the model in terms of proxels. As mentioned previously, the state vector contains also the 'age intensity' (e.g. (A, 0), (A, Δt)). The initial probability is denoted as 1.0, and the proxel-based method will convert a non-Markovian model into a Markovian one by recording the 'age intensities' in the state variables.

3. EXPERIMENTS AND RESULTS

There are many different classes of circuit models with respect to complexity, topology and types of failures. Our research will focus on distinguishing the classes of circuits to which the proxel-based method can be successfully applied for assessing reliability.

Two types of models are presented in Fig. 2. The models are taken from Srinivasan's doctoral dissertation which describes RAMP and its algorithms [4]. Connected structures A, B, C and D, have various failure rate functions (mostly based on lognormal distribution function). The first system is a series one (Fig. 2(a)), while the second one is a series-parallel one (Fig. 2(b)). The same models are analysed in RAMP using discrete-event simulation and averaging out the solutions obtained using the MIN-MAX method. As a result, a confidence interval is produced. Unlike such an approach, the solutions obtained using the proxel-based method are functions that describe the transient behaviour of the analyzed systems.

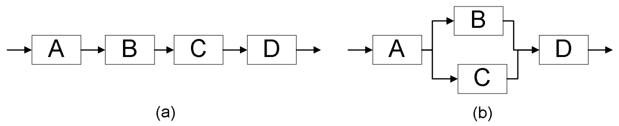

Figure 2. Example models of a series and series-parallel system.

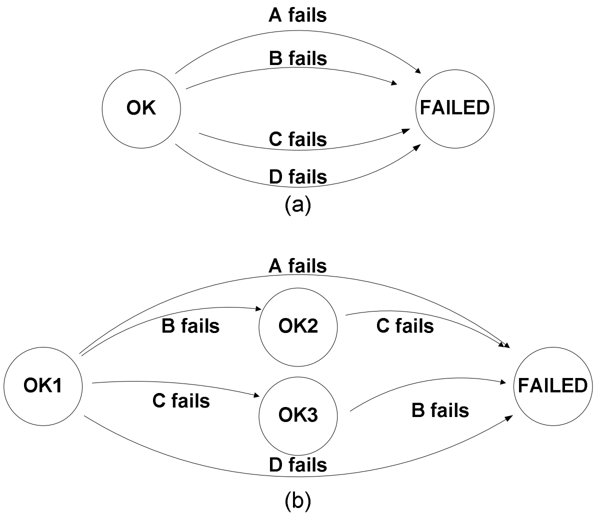

Figure 3. State spaces of the example models from Fig. 2.

In Figure 3 the state spaces of both systems from Fig. 2 are shown. The series system is represented by two discrete states, which are connected by four state changes. The series-parallel system results into four discrete states, connected through six state changes. This representation can be easily directly simulated using the proxel-based method [7].

4. SUMMARY AND OUTLOOK

The paper presents an initial attempt of applying the proxel-based method to tackle the problem of assessing reliability of the future nano-circuits. Based on our findings, we are confident that our approach can be further developed and integrated into complex EDA (Electronic Design Automation) tools. This forms part of our future R&D plans.

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