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Review of the PhD thesis

„New methods for increasing efficiency and speed of functional verification"

submitted by Ing. Marcela Šimková

Without doubt, verification is one of the major problems that currently plague the IT industry. Both, contemporary software projects as well as cutting-edge hardware designs – and even more so their combination in embedded systems – have reached a level of complexity that makes it impossible to establish sufficient freedom from design faults by traditional methods like design reviews. Without the introduction of substantially novel approaches and their further improvement the progress in these areas cannot be sustained.
The thesis of Marcela Šimková addresses this very problem, so the topic is up-to-date and extremely relevant in the chosen field of Computer Science and Engineering.

The introduction section of the thesis elaborates this fact in more detail, backed up by trends found in recent research studies, and hence serves as a good motivation for the work.

The thesis is written in English, with language and grammar being on a high level. Its structure is very adequate; it comprises 11 chapters and 2 appendices, which yields a very natural and logical flow.

Roughly the first half of the thesis presents background information and prepares the reader for the actual contributions that follow in the second half. This makes the theses enjoyable to read and relatively easy to understand. More specifically, after the motivation in Section 1, the Sections 2, 3 and 5 present history, basics and related work regarding verification, with an appropriate focus on SystemVerilog and Functional Verification. The given references are numerous and adequate. Chapter 4 is dedicated to an introduction of evolutionary computing in general, which finally focuses to genetic algorithms, since these play an important role in the later chapters.

The actual contributions follow in the second part of the thesis. To this end, Section 6 briefly summarizes the envisioned goals. With the background given in the previous chapters, it becomes very clear that these indeed present a noticeable contribution to the state of the art, both, from a practical side (procedures, tools,...) as well as from the conceptual side (algorithms,...).

Sections 7 to 10 finally present the contributions, more or less one by one.

In particular, section 7 introduces an acceleration framework for functional verification. This framework is heavily based on the author's own diploma thesis, which she has significantly extended in the course of this PhD thesis, e.g. by further accelerator blocks and the ability to also verify ASIPs and MPSoCs. Its key benefits are to run on an affordable off-the-shelf FPGA board, as well as its versatility with respect to the testbed architecture, i.e. the simulation can be gradually moved between a software simulator and the accelerator, according to the needs of the current verification task. The achievable acceleration gain is nicely explored in experiments, and different use cases illustrate the versatility of the tool.

A consequent next step in speeding up the verification process is the automated generation of verification environments from a specification, which is addressed in Section 8. In the thesis, the description of this contribution is focused to processor verification, but it is argued that the method is general enough for verification of hardware in general. An experimental case study illustrates that verification environments comprising several thousand lines of code can be automatically generated within seconds.

The conceptually most appealing part of the thesis, namely the automation and optimization of coverage-driven verification is presented in Section 9. This part definitely represents the strongest theoretical contribution of the thesis. The key idea is to have a genetic algorithm generate verification stimuli in such a way that their coverage of given properties is optimized. Given that the optimization space is prohibitively large for an exhaustive coverage in practice, an intelligent approach is needed to sufficiently explore it, and this is a particularly elegant concept towards this end. It is well motivated and elaborated. Again experimental use cases are employed to demonstrate the benefits, in particular the ability to reach overage closure earlier. Here, the reader would definitely wish to learn more details, like, e.g., which methods were applied to obtain the given tuning parameters for the genetic algorithm. However, considering the fact that the thesis presents numerous other contributions, one can understand that this has not been included in the interest of remaining within a decent page limit.

A next, very systematic step towards an optimization of the verification process is presented in Section 10. This time regression testing is targeted, and again genetic algorithms are explored for the purpose. The key idea here is to employ genetic algorithms for reducing the stimuli set originally used for verification (where some redundancy in coverage is even desirable) to a minimal subset that still achieves the target coverage. This is another conceptually and theoretically strong part of the thesis, and the obtained benefits are illustrated at the case study of an ALU.

Finally, Section 11 summarizes the work and gives some ideas for future work.

Appendix A in Section 12 presents some details about the communication protocol FrameLink that was used in experimental setups, while appendix B in Section 13 lists the author's publications and products.

I am impressed by how consequent the optimization of functional verification is pursued in this work, step by step; and these steps nicely line up to a powerful overall solution. On the theoretical side the key original contributions are the concept of using genetic algorithms for stimuli generation and for regression test vector set optimization, as well as the respective parameter tuning, which is definitely non-trivial. On top of that, by delivering a set of working tools that are carefully integrated into the standard design and verification flow, this thesis also makes considerable contributions on a more practical side. Overall it definitely represents a step forward in the state of the art of this important field.

The methodology used throughout the thesis is adequate: Marcela Šimková has demonstrated that she is well aware of the state of the art both from a research point of view (as evidenced by the bibliography) as well as a practical side, which enables her to identify scientific problems that are at the same time relevant ones in industrial reality (As such her thesis is an excellent example for

applied research). These problems are clearly stated, and in a next step concepts for solution are elaborated and evaluated, some of which are highly creative, and all of which consider practical feasibility, like solvability and manageable complexity. These solutions are always evaluated in well selected case studies and the relevant characteristics analyzed and compared with existing solutions. Overall, the goals initially set out in sections 1 and 6 have been accomplished.

Marcela Šimková has published a larger part of her results at 13 international conferences and in one journal. This is more than ok for a 4-year PhD. However, from these only two early ones (namely HVC'11 and HVC'12) are among those conferences that she herself considers most recognized in the area in Section 5.1. I believe the work, especially the later results, would have deserved publications more at those top events. In this context I am happy to see the journal publication from 2015 on the electro-mechanical application, and I recommend to continue publishing the final results in journals.
Apart from this detail, however, the publication list clearly demonstrates that Marcela Šimková has made contributions to the state of the art which have been appreciated by the community, and that she has been able to present them in an appropriate way. She definitely has found her way into the research community in her field and has been accepted there.

In summary, this thesis has brought new knowledge and has extended the state of the art. It clearly proves the author's readiness for independent scientific and creative activity in research and engineering fields.
So I can confirm that this doctoral thesis meets the requirements of the proceedings leading to PhD title conferment

Vienna, Oct 22, 2015

Assoc. Prof. Dr. Andreas Steininger

Among the questions that I would like to see discussed in the defence are the following:

Often verification also needs to be targeted to the temporal behavior of a DUV. In your thesis the focus is on verification in the value domain. Could you imagine extending your approach towards temporal verification? What needs to be changed (a) conceptually and (b) implementation-wise?

Runtime verification is being considered as a modern means to tackle the verification gap. Please illustrate the key differences between your approach, namely functional verification, and runtime verification. In comparison, where are the benefits of your approach, where the drawbacks? How do you foresee the trends?

You mention Bayesian networks as an alternative intelligent approach for coverage driven stimuli generation. Why did you finally prefer genetic algorithms?