Review of the Dissertation Thesis

Thesis title: Polymorphic circuits synthesis and optimization
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The Dissertation thesis deals with logic synthesis and optimization of polymorphic circuits. Several novel algorithms are proposed, both for two-level and multi-level synthesis.

Thesis topic and timeliness

With new emerging technologies, this topic becomes ever more important, as it recently finds its application in real technology, like silicon nanowires (SiNW) or graphene. Extensive research on this topic with application of modern logic optimization approaches was virtually missing until now. Thus, the thesis topic is timely without doubt.

The contribution of the thesis is significant; it advances the state-of-the-art in many aspects, as mentioned below.

Thesis structure

The Thesis is structured as follows:

- Chapter 1 is a general introduction, with a specification of the Thesis goals.
- Chapter 2 reviews standard and advanced logic optimization methods, in order to understand the rest of the text.
- Chapter 3 describes the concept of And-Inverter Graphs (AIGs) and algorithms used for their optimization.
- Chapter 4 introduces the concept of polymorphic electronics.
- Chapter 5 describes the previous work on polymorphic circuits optimization.
- Chapter 6 brings the first contributions of the Thesis: two algorithms for two-level synthesis and optimization of polymorphic circuits. The first one is based on extraction of expressions that differ in one operator only (NAND/NOR) and thus can be implemented by polymorphic gates. The second algorithm is more sophisticated and is based on finding common divisors. Actually, it is an application of the well-known kerneling to polymorphic logic synthesis.
- Chapter 7 describes the second contribution – application of the rewriting algorithm to polymorphic circuits optimization. From my point of view, this is the most important contribution of the thesis. Rewriting is the state-of-the-art technique, which is currently being applied to numerous non-standard design paradigms. It is highly scalable and its results can be directly applied.
- Chapter 8 is devoted to a comprehensive evaluation of the rewriting procedure and comparison with other approaches.
- Chapter 9 concludes the Thesis with proposals of further work.

Contributions

The main contributions are:

- Two novel algorithms for two-level optimization of polymorphic circuits,
- Rewriting for polymorphic circuits.

I really do appreciate all these contributions. Even though all of them are based on well-known techniques, their adaptation to polymorphic circuits is a big leap for potential emerging technologies, enabling their efficient application in practice.

I also appreciate all the effort made. Especially the rewriting must have taken a lot of time to implement.

Publication activity

The results of the Thesis were published at ten international conferences, three workshops, and in five journals. Therefore, I can assess the publication activity of the applicant as excellent.

Comments to the Dissertation Thesis text

There are several grammar mistakes (typically concerning singular/plural), but the overall English and writing style are very good.

Some comments and questions:

- Sec. 2: the description of algebraic methods could be misleading. Algebraic methods are a subset of algorithmic methods, where, in contrary to the description, Boolean algebra is not used. The counterpart are Boolean algorithmic methods, where Boolean algebra is used. In Sec. 3.1, these terms are used correctly.
- Sec. 6.2, step 3: the shared terms are not minterms, in general. You are trying to share product terms of maximum size. Minterm is a product term of size 1 (as correctly stated on the footnote).
- Sec. 7.2: the rewriting procedure should be described in more detail. Some aspects are missing at all. For example, the introduction of constant terminals, KL-cuts, etc.
- Sec. 8. 3: how many outputs did the KL-cuts have? I haven't found this information.

Questions to the defense

1. Sec. 6.2: the procedure involves solving the covering problem, which is NP-complete. It seems that you are using a simple greedy heuristic to solve it. Have you thought about more sophisticated heuristics or solving the problem exactly? Would it pay off?
2. Sec. 8. 3: how many outputs did the KL-cuts have?
3. The main problem of polymorphic gates is their size, which typically heavily exceeds the size of "standard" gates. However, this aspect is not taken into account in the optimization. Especially in rewriting, polymorphic edges are completely "for free" and the number of PAIG notes is accounted only. What are possibilities to resolve this problem?
4. Have you thought about using XOR gates in rewriting?

Final assessment

Judging from the above, it can be concluded that the applicant is highly scientifically qualified. He has proven the ability to conduct his own research and publish the results at very good conferences. Therefore,

I do recommend

the submitted thesis for the presentation and defense with the aim of receiving the Ph.D. degree.

In Davle, 23. 12. 2020

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