Review of a Doctoral Thesis at FIT BUT

Doctoral thesis (hereinafter referred to as "thesis"), title of the thesis:
Evolutionary Synthesis of Complex Digital Circuits

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I. Thesis

Appropriateness and relevance

The Thesis deals with optimization of combinational circuits using genetic programming, CGP (Cartesian Genetic Programming) in particular. Even though the logic optimization is quite a mature process, there still is a vast space for improvement. This can be documented by numerous papers on logic optimization appearing in top-level conferences and journals appearing now. Thus, the topic is definitely appropriate and relevant.

A summary of the contributions of the thesis

The Thesis proposes a CGP-based optimization of logic networks. In general, not the whole network is being optimized by CGP (which could be very time-consuming), just its parts are. Three approaches are suggested:

- A cut-based approach, similar to rewriting. In contrast to rewriting, much more gates can be processed in each iteration
- A windowing-based approach
- A reconvergent path selection algorithm, trying to exploit the network internal don't cares.

The proposed method also takes into consideration non-uniform delays distribution at the primary inputs. Again, this is what current logic synthesis tools do.

The approaches presented in the Thesis are novel without doubt and the obtained result outperform the state-of-the-art. Particularly, all the proposed methods are able further optimize highly optimized benchmark circuits, which is a great achievement.

Novelty and significance:

The outcomes of the Thesis are definitely novel and significantly contribute to the state-of-the-art. All the proposed methods are able to reduce the size of heavily optimized circuits. Thus, there can be new lower bounds of complexity determined. This is very important for both the scientific community and industry.

Evaluation of the formal aspects of the thesis:

The Thesis is organized as a collection of papers with a summary part consisted of four chapters.

Despite a few minor typos and grammar mistakes, the text is very well written and easy to follow. There are no big formal flaws.

Quality of publications

The contributions of the Thesis were published in five highly impacted international conference papers. In addition, there are also two related papers published in two reviewed conferences. From this, I'm judging the student's publication activity as sufficient.

II. Student's overall achievements

Overall R&D activities evaluation:

From the presented thesis and attached papers, it can be concluded that the applicant is scientifically qualified. She has proven the ability to conduct her own research and publish the results and thus she is fully eligible to achieve the Ph.D. title.

Comments and questions

- Sec. 1.1: "In order to explicitly support XOR gates in logic synthesis, XOR-AIG representation was introduced by Fiser et al. [17, 9]." – actually, the XAG concept has been (silently) introduced in ABC in 2012 or so. Unfortunately, without mentioning that in any publication. Btw. the reference to [9] is wrong.
- Sec. 2.2: why do you think there is a problem with scalability in rewriting? It can be freely used for networks of any size; its scalability depends just on the size of the cut, which is given by the designer of the algorithm (i.e., by the size of the cuts).
- Sec. 2.1 vs. Sec. 2.2: in 2.1, you define don't cares as the external ones (at PIs). However, in Sec. 2.3 there are internal don't cares mentioned. This could be confusing.
- Sec. 2.5: how is the fitness calculated?
- Rewriting algorithms allow for a "zero-cost replacement". This means, some structure is allowed to be replaced by another, even if there is no cost improvement (nor a deterioration). Do you support such an option? From Alg. 1, it does not seem so.
- Fig. 3.2: there are 10 nodes, not 9. Or am I missing something? Btw. a cut of a node is a set of leaves only, by definition. What is illustrated in this example, is called a "cut set".
- Fig. 3.3.: there are 11 nodes in the window, not 10. The same holds for Fig. 3.4. Or am I missing something?
- What are the run times? I'm missing this information in Table 3.1.
- What has been the quality (size) measure in the experiments presented in Table 3.1? The number of AIG nodes?
- It would be nice to map the resulting netlists to 6-LUTs and compare the results with the best ones ever obtained, for the EPFL benchmark. These results are presented at the referenced webpage.

III. Conclusion

The thesis and the student´s achievements meet the generally accepted requirements for the award of an academic degree Ph.D. (in accordance with Section 47 of Act No. 111/1998 Coll., on higher education institution). Therefore,

I do recommend

the submitted thesis for the presentation and defense.

In Prague, 11. 5. 2024

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