

Doctoral thesis (hereinafter referred to as "thesis"), title of the thesis:

APPLICATIONS OF FORMAL METHODS IN APPROXIMATE COMPUTING

VYUŽITÍ FORMÁLNÍCH METOD V PŘIBLIŽNÉM POČÍTÁNÍ

Name of the doctoral student (hereinafter referred to as "student"), name and surname:

Ing. JIŘÍ MATYÁŠ

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I. Thesis

Appropriateness and relevance

The area of the research presented in this theses is appropriate and relevant to the actual research area, especially in today massively exploitations of embedded systems. The approximate computing methods seems to be promising, especially when the design methods will be automatize, scalable and formally verified. The decreasing of the area overhead and power consumptions are key challenges, which should be taken into account not only in the research but in the industry, too. This thesis can help in this area and could lead to more practical using of approximate circuits.

A summary of the contributions of the thesis

The main goals and principal aims of this thesis is to improve the **automated** search-based methods for designing high-quality approximate arithmetic circuits. The key steps to achieve it are the following:

- to improve the algorithm that creates the candidate approximate solutions, and
- to improve the procedure that evaluates the quality of a given candidate approximate solution

Specific contributions of the candidate are based on the original solutions and improvements based on theoretical methods:

- The improvement of the existing error evaluation approaches based on Boolean satisfiability solving (SAT), novel miter constructions for the evaluation of the errors using SAT and a newly designed verifiability driven search strategy. Using a framework based on the Cartesian Generic Programming shows significant improvements of the capabilities of the search based approximate arithmetic circuit design. Details are described in Chapter 3 and presented at ICCAD (2017) and Eurocast (2020) conferences.
- The adaptive approximation method and framework leading to the improvements in the quality of the approximate solutions. It is presented in Chapter 4 and published at Journal (2020)
- All methods were implemented, experimentally evaluated, documented and explained in detail using and ADAC tool – original FIT tool, presented at CAV conference (2018).

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- Chapter 6 describes other possibility and experiments based on a combination of a satisfiability based exact synthesis optimisation approach with the approximation techniques with the aim to help the evolutionary algorithm to escape local optimums (presented at SAT conference in 2020). The last Chapter 7 proposes a new mutation operator for Cartesian Generic Programming especially for the arithmetic circuits' approximation (published at Journal in 2022).

Novelty and significance:

The novelty is in the improvements of the synthesizer and the analyser which are base of automated search-based method (algorithms) for today actual research area: automated approximate arithmetic circuits design. This can lead to more practical and faster design of the computational structures with limited level of area overhead, power consumptions with guaranteed fault limits.

Evaluation of the formal aspects of the thesis:

The structure and organization of this Thesis are adequate, only the different length of the chapters can be surprising. Chapter 2 describing the state-of-the-art is the longest one (33 pages), the most important chapters 3 and 4 match the content and importance, but the others are much shorter.

The text is written in plain English and text and descriptions are easy to read and understand. There are only several non-standard things, e.g. the same titles of subchapters 2.2.5 and 3.2.2., a missing special list of author's publications and their inclusion in chapter 1.3. named Author's Contribution, where, on the other hand, the list of contributions is missing ...

Quality of publications

The research results has been published at an appropriate level, as concern both the quantity and quality. All contributions described in the thesis were published, but I have a problem with the statements (see page 7, the end of the first paragraph of subsection 1.3): *"The author of this thesis took **an important part** in the formulation of the research ideas, designing methodological approaches, and writing of the articles below."* and *"The author **played an essential role** in the implementation and experimental evaluation of the proposed methodologies."* Please specify more precisely what means *"an important part"* and *"played an essential role"*. So explain why the author's name is never listed first on these publications. See e.g. to other FIT VUTBR disertation thesis: https://www.vut.cz/www_base/zav_prace_soubor_verejne.php?file_id=206462, there are for each publication, expressed as a percentage of the author's share.

II. Student's overall achievements

Overall R&D activities evaluation:

I can state that Jiří Matyáš thesis, the results included into it, and other scientific achievements (ADAC tool used the formal research experimental evaluations, new ideas to continue his research and publications) indicate that he is a person with scientific erudition and creative abilities.

Assessment of other characteristics and questions:

- See my remarks in "Quality of publications" and explain them.
- Is there any limit for the ADAC tool concerning the approximate arithmetic circuits size?

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- If the final circuit will be made up of more approximate units, won't the allowed limit errors be multiplied? In other words, would it be possible to somehow (automatically and formally) treat this merging as well?
- Do you have any practical results of implementing arithmetic circuits?
- Do you plan to widespread your results to industry?

III. Conclusion

Finally, despite of some remarks (and after their satisfactory explanations) I have to declare that PhD theses **APPLICATIONS OF FORMAL METHODS IN APPROXIMATE COMPUTING** by **Ing. Jiří Matyáš** designed **and** created new methods and carefully described their evaluations. They are original ones and provide new insight on the recent digital design methods in the proposed area.

Therefore I can declare that the thesis and **Ing. Jiří Matyáš** achievements until now meet the generally accepted requirements for the award of an academic degree (in accordance with Section 47 of Act No. 111/1998 Coll., on higher education institution). I agree for his graduation by the title PhD.

Place Praha, 20. 09. 2023

Signature of the reviewer: