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Ph.D. Thesis Review

Author: Ing. Jiří Kučera

Title: New parallel and regulated automata and grammars

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Reviewer: doc. RNDr. Daniel Průša, Ph.D., Czech Technical University in Prague

Summary

The thesis by Ing. Jiří Kučera studies automata and grammar models based on the principles of regulation and parallelism. The following four models are introduced:

- state-synchronized automata systems,
- absolutely unlimited deep pushdown automata,
- jumping pure grammars, and
- $k\#\$\text{-}$ rewriting systems.

The thesis comprises 123 pages and is structured into three parts. The first part explains motivation, lists fundamental notions from the theory of formal languages and surveys related existing systems. The second part gives formal definitions of the proposed models and presents results on their expressive power. Finally, the third part summarizes the obtained theoretical results, sketches possible practical applications and outlines directions for further research.

Majority of the achieved results were published in three international journals (two of them indexed in Web of Science) and one international conference.

Evaluation

The models proposed by the author are novel and well motivated. They are based on principles fundamental for the theory of formal languages and they extend research recently done by others. The author's research is theoretical, but he explains connections with application areas such as compiler design or genetic algorithms.

The thesis focuses on main questions related to the models. It is shown how their recognition power changes with the change of parameters. The families of accepted/generated languages are compared with the levels of the Chomsky hierarchy. In some cases, the models are Turing complete.

I consider the following to be the most important results:

- Every recursively enumerable language is accepted by a deterministic state-synchronized automaton system of degree 2.
- Languages accepted by absolutely unlimited deep pushdown automata (AUDPA) coincide with the recursively enumerable languages, while the languages accepted by propagating AUDPAs coincide with context sensitive languages.

- There is a complex hierarchy among language families generated by jumping pure grammar variants.
- $k\#\$\text{-rewriting}$ systems are equivalent to programmed grammars of index k and more powerful than $\#\text{-rewriting}$ systems of index k , which are equivalent to state grammars in k -limited way.

The achieved results are non-trivial. To prove them, it was often required to come up with technically demanding, lengthy proofs. The author handled this well. He demonstrated his ability to clearly present such type of proofs.

From a formal point of view, the text of the thesis is of a high quality in terms of language and mathematical notations. It is written in very good English, its structure is appropriately chosen, it is clear and comprehensible.

From the negative side, there are a few places in the text where formulations should be more precise or where more details could have been provided. Here are some examples:

- Page 7: *“Sets whose members are other sets are called families of sets rather than sets.”*
From the point of view of set theory, the elements of sets are always sets.
- Page 9: *wa* is used before it is explained what concatenation is.
- Page 29: It would be useful to explain the meaning of indexes s , lj , rj and j .
- Page 37: It is confusing that Γ is used to denote a state-synchronized automaton and at the same time Γ_i is used to denote a pushdown alphabet.
- Page 45: Statement (a) is unnecessary because it directly follows from statement (b).
- Page 48: The formulations of Theorems 4.2.21 and 4.2.22 do not clearly say that the theorems hold for every $n \geq 1$.

In addition, the finding that the relationship between $\#\text{-rewriting}$ systems and $k\#\$\text{-rewriting}$ systems implies the relationship ${}_k\mathbf{PRG} \subset \mathbf{ST}_k$ between programmed and state grammars should have been more elaborated. The concluding chapter does not say clearly whether the implied relationship is a new result or not.

However, these are only minor issues that do not affect much the quality of the thesis.

The author’s CV suggests that his professional interests, activities and experience have a broader scope, which includes both theoretical computer science and its applications.

Regarding the author’s publications, I consider them to be sufficient, although I believe that the results would have deserved to be published at more conferences focused on the theory of formal languages.

Conclusion

In my opinion, the submitted thesis is of a high standard. It is well motivated and it gives a useful contribution to the state-of-the-art of the theory of formal languages.

The author definitely proved his ability to perform research and to achieve scientific results.

I believe that the thesis meets all the generally accepted requirements for doctoral thesis. I therefore recommend awarding the PhD degree to Ing. Jiří Kučera.

Prague, September 14, 2021

doc. RNDr. Daniel Průša, Ph.D.