Software Modeling and Verification Chair | RWTH AACHEN UNIVERSITY

— Master's Thesis —

Termination Rules for Probabilistic Programs

What is it all about?

Probabilistic programs extend deterministic programs by a random choice about which code branch is executed next. They can be defined by the following grammar:

$$\mathrm{c} \coloneqq \mathrm{skip} \mid x \coloneqq \mathrm{a} \mid \{\mathrm{c}\}[\mathrm{p}]\{\mathrm{c}\} \mid \mathrm{c}; \mathrm{c} \mid \mathrm{if\ b\ then\ c\ else\ c\ end} \mid \mathrm{while\ b\ do\ c\ end}.$$

Because of loops, probabilistic programs may terminate with any probability between 0 and 1. We say that a probabilistic program terminates almost surely (AST), if it terminates with probability 1. Proving AST of a probabilistic program is an involved task, but recently Majumdar et al. [MS25] developed sound and complete proof rules for proving AST. These proof rules work on probabilistic control-flow graphs which are models of probabilistic programs (see e.g. [CGMZ22]).

What is to be done?

The goals of this project are:

1. Develop a translation from probabilistic programs to control-flow graphs
2. Understand and apply the AST rules to multiple probabilistic programs (e.g. the Fast Dice Roller: [Lum13])
3. Optional: Examine variants of the AST rules that work directly on program level

This list is of course non-exhaustive! The above suggestions may be changed, shortened and/or extended while we work on our project and gain more insights on how difficult the topic is.

What we expect:

- Solid background in theoretical computer science and maths – ideally you have already taken theoretical CS electives
- Passion and endurance for solving theoretical problems

What you can expect:

- Get a chance to work on relevant problems of both theoretical and practical nature
- You can work in the student room at our chair – we have a coffee machine, lots of tea and sometimes cookies :)

Apply

- Daniel Zilken (daniel.zilken@cs.rwth-aachen.de)
  Please introduce yourself briefly and say why you're interested in this topic!

References

[CGMZ22] Krishnendu Chatterjee, Amir Kafshdar Goharshady, Tobias Meggendorfer, and Dorde Zikelic. Sound and complete certificates for quantitative termination analysis of probabilistic programs. In Sharon Shoham and Yakir Vizel, editors, *Computer Aided Verification - 34th International Conference, CAV 2022, Haifa, Israel, August 7-10, 2022, Proceedings, Part I*, volume 13371 of *Lecture Notes in Computer Science*, pages 55–78. Springer, 2022.

[Lum13] Jérémie O. Lumbroso. Optimal discrete uniform generation from coin flips, and applications. *CoRR*, abs/1304.1916, 2013.

[MS25] Rupak Majumdar and V.R. Sathiyanarayana. Sound and complete proof rules for probabilistic termination. *Proc. ACM Program. Lang.*, 9(POPL), January 2025.