

Short-Term Scientific Mission Grant - APPLICATION FORM¹ -

Action number: CA20111

Applicant name: Ján Perháč

Details of the STSM

Title:

Proof Theory for Programmers: Promoting Output of Theorem Provers to Formative Feedback for Computer Science Students

Start and end date:

01/06/2024 to 09/06/2024

Goals of the STSM

Purpose and summary of the STSM.

(max.200 word)

Courses involving formal methods, logic, and formal proofs require mathematical proficiency which is uncommon among computer science students. Our research suggests making formal methods approachable by computer science students' by taking a programmer's perspective on applying formal methods.

Our research teams from the University of Oslo, led by Michael Kirkedal Thomsen, and from the Technical University of Košice, led by Ján Perháč, are currently developing an interactive teaching theorem prover, consisting of two parts: A teacher's DSL for specifying deductive systems and exercises, and a student's DSL for specifying solutions to exercises. The error messages provided by the student DSL are guided towards a desirable solution by suggested solutions provided by the teacher's program.

The main goal of this STSM is to continue development and discuss recent results from the first experiments of using our theorem prover in teaching. These experiments are planned for the 2024 spring semester in relevant courses at both universities. The discussion should lead to a plan for conducting research in the area of data-driven teaching methods that use theorem provers to check students' proofs. Additionally, we plan to explore the potential use of generative AI to provide formative feedback where students' proofs do not hold.

¹ This form is part of the application for a grant to visit a host organisation located in a different country than the country of affiliation. It is submitted to the COST Action MC via-e-COST. The Grant Awarding Coordinator coordinates the evaluation on behalf of the Action MC and informs the Grant Holder of the result of the evaluation for issuing the Grant Letter.

Working Plan

Description of the work to be carried out by the applicant.

(max. 500 word)

During our meeting, we will focus on the following topics:

- Discussion on the further development plan of our theorem prover.

Future iterations on our theorem prover `onlineprover` [1] include the development of a web-application/editor that help students type in solutions to exercises handed out by their teacher. The editor should enable students to choose a syntax which is closely related to that which can be found in their course materials (e.g. Gentzen style).

- Discussion of results from the first experiments.

Through the web-application, we aim to collect anonymous data submitted by students about their usage of the theorem prover (how often do they submit a proof that does not hold? What do they typically change when presented with a certain error message etc?). The discussion should lead to an agreement on which data and how it should be collected, in order to enable us to conduct research in the area of data-driven teaching methods that use theorem provers.

- Use of generative AI to provide formative feedback.

In usual programming language theory, it is difficult to answer philosophical questions such as *"what is a good error message"*. However, in data-driven teaching, we hope to be able to make such questions concrete by asking about measurable outcomes such as *"do students converge on a correct proof faster if the error messages have been promoted to formative feedback by a generative language model"*.

- Extending our network.

We plan to discuss the use of our tool with other potential users from different universities. Therefore, we plan to define the `While` (sometimes called `IMP`) imperative language, and the `FUN` functional teaching language, along with their semantics, in our tool. This will include a set of relevant exercises that can be employed directly in a course, and it will also serve as a tutorial for teachers that wish to define other languages.

References:

[1] Web-page of the `onlineprover` project: <https://onlineprover.github.io/>

Expected outputs and contribution to the Action MoU objectives and deliverables.

Main expected results and their contribution to the progress towards the Action objectives (either research coordination and/or capacity building objectives) and deliverables.

(max. 500 words)

Our STSM will contribute to the main goal of the action by enhancing the interoperability and usability of proof systems, mostly in "WG1: Tools on Proof Systems Interoperability". Specifically, we will

contribute to the objectives and deliverables as follows:

- *Facilitate access to formal verification techniques in education and other scientific domains.*

Our theorem prover is developed as a teaching tool, motivated by the goal of providing easy access to formal methods in education. Our hypothesis is that "traditional" proof assistants such as Coq or Isabelle are not well-suited for courses where students need to study proof theory and formal proofs due to the significant learning curve, especially without prior knowledge of functional programming. Our tool aims to be easy to use, with simple and intuitive user interface, so the users can focus on the original goal - formal proofs.

- *Enhance the effectiveness and accessibility of program verification techniques for all stakeholders.*

One of the main goals of our theorem prover is to enable data-driven teaching methods - In doing so, we will also be able to generate an empirical basis for studying student learning, which in turn will improve the accessibility of our tool. In time we will learn how to make theorem provers more accessible in general.

- *Foster collaboration among members of diverse communities working on proofs in Europe and create an inclusive network of researchers in Europe with lasting collaboration beyond the lifetime of the Action.*

One of the objectives of this STSM is to expand our network of colleagues from different universities, including both Inclusiveness Target Countries (ITCs) and non-ITCs, as well as young researchers.

- *Actively support young researchers, individuals from under-represented genders, and teams from regions with limited capacity.*

I, Ján Perháč, am a young researcher from Slovakia, visiting Michael Kirkedal Thomsen. During this visit, I will also collaborate with young researchers, including Michael's PhD students, Joachim Tilsted Kristensen and Lars Vadgaard.

- *Detailed technical report on the evaluation of techniques for learning proof search guidance and premise selection in automated theorem provers.*

We are preparing a survey paper on the use of formal methods and theorem provers in teaching. Parts of the survey can be incorporated into the technical report.