Short-Term Scientific Mission Grant
1. APPLICATION FORM[1] -

Action number: CA20111

Applicant name: Maribel Fernandez

Details of the STSM

Title: Representation of Proofs via Hierarchical Higher-Order Port Graphs

Start and end date: 11/09/2023 to 18/09/2023

Goals of the STSM

Purpose and summary of the STSM. *(max.200 word)*

Our long-term goal is to develop a graph-based tool for the representation, analysis and management of proofs using graph rewriting techniques. We hope graph-based proofs can serve as a common language for the encoding of proofs generated by different proof systems. By designing a general proof representation formalism based on port graphs, we hope to contribute to the general aim of this COST Action: boosting the interoperability and usability of proof systems.
The goals of the STSM are:
- Complete the specification of intuitionistic logic using hierarchical port graphs, and then consider the representation of proofs in powerful logical frameworks (such as LF modulo, which is the basis of Dedukti).
- Plan the next steps towards the design of a domain-specific language for proof representation. We plan to develop the foundations for a graph-based proof management environment (in the style of PORGY but specifically tailored to the management of proofs). This will require some engineering work as well as more research on proof formats and proof management. This research can also shed light on closely related problems, such as, proof visualisation, proof search, proof maintenance.

Working Plan

Description of the work to be carried out by the applicant. *(max.500 word)*

In previous work, we defined graphical representations of proofs in intuitionistic logic using higher-order extensions of interaction nets (TERMGRAPH 2011). Recently we revisited this work and studied representations using hierarchical higher-order port graphs (HOPs), which generalise higher-order interaction nets by providing mechanisms to structure proofs and to build modular proofs. We believe HOPs are a good candidate to unify previous work on graphical formalisms for proof representation: port graphs have already proven to be a good foundation for a modelling tool (they are the basis of PORGY), and HOPs inherit the properties of port graphs while providing additional structuring and abstraction features. Hierarchical port graphs have been successfully used to model financial processes and computation models (see e.g. Ene, Fernandez and Pinaud's papers at WPTE 2018 and

[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.

AMINSE 2019), but had not yet been applied in the area of proof representation. On this basis, we first checked their suitability for proof representation by considering some paradigmatic logics. The results so far are promising, and to advance on this line of work we propose the following next steps:
- consider the use of hierarchical port graph rewriting rules to specify operations on intuitionistic logic proofs (e.g., proof normalisation), and define strategies to control the rules to achieve expected results (e.g., to ensure the uniqueness of normal forms).
- consider more involved logics, such as nominal logic (which is defined as a theory in first-order logic), or higher-order logics used in powerful proof assistants. We expect that by using hierarchical port graphs as a representation language for paradigmatic logics, we will be able to distil general principles for the encoding of proofs, which can guide the design of a domain-specific language for proof representation. In a later stage, we will consider the representation of proofs in powerful logical frameworks, such as Dedukti.
To advance in this work more effectively, we are planning an in-person meeting over one week in September.
We plan to continue this work after the visit, with the aim of developing the foundations for a graph-based proof management environment (in the style of PORGY but specifically tailored to the management of proofs).

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)*

Below we list the main expected results, their relevance for the Action, and contribution towards the deliverables of the action.

- Encodings of proofs in paradigmatic logics (intuitionistic logic, linear logic, nominal logic) using hierarchical higher-order port graphs, and analysis of their properties via graph rewriting rules. This will be reported in a paper describing encodings of proofs and proof transformations using hierarchical port graph rewriting). This will also contribute towards Action Objective 8 and it is a necessary step towards the next output.
- Encodings of proofs in powerful logical frameworks using hierarchical port graphs. Analysis of the suitability of graph representations of proofs as a tool to communicate and exchange proofs between different proof assistants, and as a visual tool to facilitate proof construction, extension and update. The latter is relevant to the work done in WG4 (Libraries of formal proofs), whose aim is to investigate approaches to efficiently maintain libraries of proofs, so that they can be modified and queried by users without expert knowledge of the system used to develop proofs. We believe that graphs, which provide a visual representation, can facilitate the understanding of proofs and contribute towards the aims of WG4. We expect this will give rise to collaborations with other teams (in particular Dedukteam) and contribute towards the deliverables of the Action (in particular: description of proof formats, translation of proofs from different systems, tools to manage proofs and for searching and querying collections of proofs).
- Identification of the main features required for a general graph-based language for proof representation and manipulation. Design of a domain-specific version of a graph-based modelling tool, such as PORGY, to model/analyse proofs in various systems of interest, and link the modelling tool with proof assistant tools. For this, we will seek input from members of the PORGY team in the university of Bordeaux, with whom we have a long-standing collaboration, as well as from members of Dedukteam.