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

Action number: CA20111

Applicant name: Luca Ciccone

Details of the STSM

Title: Unification Library & Mechanized Type Inference in Agda

Start and end date: 04/09/2022 to 18/09/20222

Travel cost: ~530e flight + 40e subway + 10e airport=>centre bus + ~40e centre=>airport night taxi

Accommodation & Living cost: ~1500e hotel + 300e

Requested grant: 2450e

Goals of the STSM

This STSM is a continuation of the previous "*Mechanized Type Inference in the Linear π-Calculus*". There, we started investigating the problem of mechanizing a type inference algorithm for the pi-calculus [2]. Such algorithm is based on a unification one; in particular, we referred to [1].

Achievements of the previous STSM:

1. Mechanization of **soundness/completeness** theorems of unification
2. Mechanization of a **sound** type inference algorithm for the **shared** pi-calculus

Goals of this STSM:

1. Prove the **completeness** of the inference in the shared pi-calculus (We would like to publish the results in a conference like CPP/ITP)
2. Extend the results to the **linear** pi-calculus
3. Extend the results to **infinite types**
4. Add **(fair)subtyping** constraints

Each step (2,3,4) requires a variant of the unification algorithm. Hence, we aim at building a library that can be used in the context of type inference in many scenarios such as for the lambda calculus. The development points 1 and 2 is ongoing and all the material is available at

https://github.com/LcicC/CoContextualPi

Furthermore, sessions can be encoded using linear channels [7]. We expect that the results we are obtaining can be the bases for investigating type inference in the context of session types.

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

We decided to split the work in some independent phases that have the advantage of being completely modular, as explained later.

Shared pi-calculus

We will instantiate the first unification algorithm that we mechanized in the previous STSM to formalize the **completeness** of the type inference for the **shared pi-calculus**. The only existing mechanization of [1] is by Wen Kokke

https://github.com/wenkokke/FirstOrderUnificationInAgda

However, it has a different representation of the terms, it contains some unsolved goals and misses a completeness proof.

Compositional type inference

We will identify an appropriate formulation of the linear pi-calculus that is amenable to be mechanized and for which it is possible to define a **compositional type inference** algorithm based on a co-contextual type system [10]. We will study how to locally solve the constraints. We will need a variant of the unification algorithm which is based on a signature to take into account also polarities.

Support for recursive processes and types

Many communication protocols describe arbitrarily long conversations. The encoding of such protocols in the linear pi-calculus requires support for **recursive types**. In this phase we will extend the process language to include recursive processes, we will identify a suitable Agda representation of recursive **(possibly infinite) types**. Also in this case, we will need to change the unification algorithm to deal with infinite terms.

Type inference with (fair) subtyping

Subtyping for session types has been shown to be important for broadening the range of processes that are well typed [4]. In this phase we will enrich the inference algorithm with support for subtyping. This will require a generalization in the representation of type constraints from equalities to **subtyping relations**. At last, we aim at using **fair subtyping** [3], a liveness preserving refinement of the relation mentioned so far. In this context we will mechanize a new, recently developed [6], characterization of such relation which is based on a purely coinductive **inference system**. We will have the chance at using a library [5] for supporting Inference Systems in Agda that we developed last year and that we are planning to integrate in the Agda standard library.

As previously noted, each step will require a sound and complete variant of the unification algorithm that we mechanized during the previous STSM. Moreover, each research line can be treated independently so that we will be able to inspect the most valuable contributions first. For example, we can integrate subtyping before moving to infinite types. At the moment, we are working on the first two phases.

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

Working Groups: WG3 and WG4

At the end of the mission, we expect to obtain an Agda mechanization of a **type inference** algorithm for the **linear pi-calculus** that is **compositional** (allowing for the analysis of independent processes in isolation) and that supports **recursive types**. We will also pave the way to the integration of **subtyping** in the inference algorithm. At the same time, we will develop an **Agda library** based on all the needed variants of Conor McBride's unification algorithm [1]. For these reasons, we think that the STSM will contribute to both **WG3** and **WG4**. The addition of the library as a significant contribution is one of the results of the previous STSM. Such library can be imported by users working on similar type inference problems by properly instantiating the terms. Moreover, the mechanization of the new characterization of fair subtyping will be used (together with the results in [3]) as a sophisticated use case for the Inference System library [5].

Once again, the STSM will also be the occasion to foster the collaboration between two different research groups that so far have met only once. However, in these last years both groups worked on strictly related topics [8,9]. Indeed, besides the previous visit, Ornela Dardha has been organizing the first two editions of the VErification of Session Types (VEST) workshop. The workshop aimed at gathering people from two different research communities, that working on session types and that working on proof assistants. Due to the pandemic, both editions have been held online.

So, the STSM is in line with the capacity building objectives of EuroProofNet, by bringing "together members of the different communities working on proofs in Europe" and by "actively supporting young researchers".

As a final note, the collaboration between the two involved groups continued after the previous STSM giving some fruitful results that we hope to officially publish. However, during the first visit we had to spend most of the time reflecting on how we could approach the problems. This time, since the main development has started and we are currently working together by arranging remote meetings, we expect that the visit will be mainly focused on the contributions mentioned in the previous section. I am a third year PhD student and by PhD will conclude in October 2022. The previous STSM has been the very first in person experience and I hope to contribute on the topics on which we are collaborating before the end of my PhD. Hopefully, these visits will be the bases for future collaborations.

References

1. Conor McBride: **First-order unification by structural recursion**. Jun. Funct. Program (2003)
2. Luca Padovani: **Type Reconstruction for the Linear π-Calculus with Composite Regular Types**. Log. Methods Comput. Sci. 11(4) (2015)
3. Luca Ciccone, Luca Padovani: **Inference Systems with Corules for Fair Subtyping and Liveness Properties of Binary Session Types**. ICALP 2021: 125:1-125:16
4. Simon J. Gay, Malcolm Hole: **Subtyping for session types in the pi calculus**. Acta Informatica 42(2-3): 191-225 (2005)
5. Luca Ciccone, Francesco Dagnino, Elena Zucca: **Flexible Coinduction in Agda**. ITP (2021)
6. Luca Ciccone, Luca Padovani: **Fair termination of multiparty sessions**. ECOOP (2022)
7. Ornela Dardha, Elena Giachino, Davide Sangiorgi: **Session types revisited**. Inf. Comput. 256: 253-286 (2017)
8. Uma Zalakain, Ornela Dardha: **π with Leftovers: A Mechanisation in Agda**. FORTE 2021: 157-174
9. Luca Ciccone, Luca Padovani: **A Dependently Typed Linear π-Calculus in Agda**. PPDP 2020: 8:1-8:14
10. Uma Zalakain, Ornela Dardha: **Co-Contextual Typing Inference for the Linear π-Calculus in Agda.** TyDe 2021