

Report on the outcomes of a Short-Term Scientific Mission¹

Action number: CA20111

Grantee name: Violet Ka I Pun

Details of the STSM

Title: Static guarantees of confluence in actor languages

Start and end date: 16/04/2023 to 23/04/2024

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

The plan of this STSM is to explore the techniques that can guarantee deterministic behaviour for concurrent programs, in particular actor (and active object) programs, as part of the extension of the earlier work of the grantee with the host of the STSM [2]. We planned to approach this from three perspectives:

- (1) relaxing the communication topology between objects of our previous work;
- (2) using De Bruijn's proof framework for confluence for families of rewrite relations in abstract reduction systems [1] to show the confluence properties in the operational semantics of actor languages; and
- (3) proving the properties using Coq.

To achieve these, the activities carried out during the STSM are as follows:

- We formalised De Bruijn's proof framework in Coq and proved the theorem and lemmas stated in the paper [1]. Through the formalisation, we identified some minor errors in the "pen and paper" proof, and have them corrected in the Coq proof.
- We first investigated how to apply De Bruijn's proof framework to guarantee deterministic behaviour for concurrent programs in actor (or active object) languages; and realised that such a framework are applicable for concurrent programs in general. We therefore decided to first show how the framework can be generalised to prove deterministic behaviour for concurrent programs, and then to investigate the specifics for actor programs.

¹ This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

- We formalised the syntax and the semantics of a concurrent lambda calculus with futures and cooperative scheduling in paper as well as in Coq. We also identify a simple example in the calculus where De Bruijn's proof framework can be applied to show deterministic behaviour.
- We also have formalised of a core actor language and proven the confluence properties for programs in this language by structuring the reductions in two levels: a deterministic kernel where program reductions can be reordered; and reductions in the other level are restricted to certain order.

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

The STSM has partially achieved the planned goals:

- A Coq proof of confluence properties specified in De Bruijn's framework.
- A preliminary result of the confluence properties for actor languages formalised in the form of a Coq proof.
- The planned research work has been divided into two parts: one for using De Bruijn's framework to show confluence properties for concurrent programs, and the other one specific for actor programs.
- A simple concurrent lambda calculus with futures and cooperative scheduling for the first part of work described in the point above.

We plan to have a follow-up meeting in early October prior to or after a workshop regarding active object language organised by the host institute. Meanwhile, we decide to continue the collaboration remotely and meet digitally for discussion when necessary.

References:

- [1] Endrullis, J. and Klop, J. W.: De Bruijn's Weak Diamond Property Revisited. *Indagationes Mathematicae*, 24(4):1050 – 1072, 2013. In memory of N.G. (Dick) de Bruijn (1918–2012). <https://doi.org/10.1016/j.indag.2013.08.005>
- [2] Henrio, L., Johnsen, E.B., Pun, V.K.I: Active Objects with Deterministic Behaviour. In: Dongol, B., Troubitsyna, E. (eds.) IFM 2020. LNCS, vol. 12546. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-63461-2_10