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

Action number: CA20111

Applicant name: Sandra Alves

Details of the STSM

Title: Higher-order effectful programming languages and quantitative type systems

Start and end date: 21/06/2024 to 22/06/2024

Goals of the STSM

Purpose and summary of the STSM.

(max.200 word)

The goal of this project is to continue an ongoing investigation on quantitative computational properties of languages with effects. In recent years we have explored the use of quantitative type-systems for languages with global state, which allowed us to study and measure quantitative properties related to time (evaluation steps) and use of memory (locations on global state), for both the call-by-value (CBV) and the call-by-name (CBN) paradigms. This has allowed us to unveil crucial quantitative relations between typing (statics) and reduction (dynamics) of programs.

Building on this knowledge our aim is to obtain a quantitative system for a general framework extended with different algebraic effects. Our aim is not only to obtain quantitative properties in a formalism that is capable of capturing different reduction strategies, such as the Call-By-Push-Value (CBPV) or the Bang Calculus, but also to apply our quantitative techniques to other effects that can be found in programming languages.

This is not our first attempt at obtaining a quantitative model for a general framework with effects, but we believe that our recent results on the interaction of global memory with both CBN and CBV have given us valuable insights on how different evaluation strategies impact effectful computations.

Working Plan

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

(max.500 word)

Our first step will be to chose the appropriate language to develop our general framework, as well as the specific algebraic effects we want to capture. Given that our previous results were devoted to global memory, we will use this opportunity to study other computational effects, such as parallelism,

[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.

exceptions, non-determinism, and I/O.

After defining our (untyped) language and an appropriate operational semantics we will study properties of the language with respect to its operational semantics. In particular we will characterize a suitable notion of normal form, by means of a proper grammar, and prove the soundness and correctness of the grammar with respect to the reduction relation.

Next we will focus on finding the correct characterization of programs that "go wrong", by properly understanding what are the possible syntax clashes or blocked computations of the defined language. This will guide our design of and appropriate type system that will discard these ill-formed programs. Our goal is to define a suitable notion of "correct" normal-forms, which correspond to well-formed irreducible terms, by means of a grammar, and prove the soundness and correctness of the grammar with respect to the reduction relation.

Having defined and studied the untyped language, we will move to the definition of an appropriate type system capable of, not only identifying the programs that will behave correctly, but also provide interesting quantitative information about the dynamics of these programs. We will use our knowledge and experience on quantitative (non-idempotent intersection) types. Furthermore, we will rely on the insights we have gain while studying the interplay between quantitative types and call-by-name and call-by-value with global state, in order to obtain a type system for a term language that can incorporate both paradigms as well correctly characterising its interplay with our specific effects.

Our final aim is to prove the soundness and completeness of our type system with respect to our language. We aim at characterizing not only termination, but also to obtain interesting quantitative results about the operational semantics. Following our previous results for global state, our goal is to obtain quantitative measures for evaluation steps, which can simultaneously be exact and discriminate between the different dynamics of the language (i.e., that give separate measures for pure functional steps and effecttful interactions).

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)

Resource aware computation is a very much relevant area of research, with applications in the implementation of different functional programming languages and/or modern proof-assistants. Quantitative type-systems have been extensively used in recent years to reason about languages from a quantitative point of view. There exist such quantitative studies for the Bang Calculus (a term language connecting CBPV and Linear Logic) but, to the best of our knowledge, there is no previous general quantitative formalism that also incorporates effects. Our previous (recent) results explore effect interaction in both call-by-name and call-by-value, by means of a global state, but there is still the open question of whether or not this can all be incorporated in the same framework. Recent results by Gavazzo et al. (2024) gave a generic framework for algebraic effects, but their approach lacks any quantitative results. This is an active area of research, which continues to attract growing attention. We believe this makes our project a timely one.

The expected results of this project are very much related to the objectives of WG3: dealing with side effects in a clear way facilitates the formal verification of programs. Furthermore, by defining a quantitative general typed language that incorporated effects, we are contributing to the development of effectful type theories, which aligns with the main goal of WG6.

Our previous work on languages with global state was initiated in the course of a EuroProofNet STSM and resulted in a conference paper (already published) and a journal paper (currently in submission). We expect to obtain similar deliverables for this new project.