university of groningen

Faculty of Science and Engineering

Bernoulli Institute for Mathematics, Computer Science, and Artificial Intelligence

Prof. dr. Jorge A. Pérez
T +31-50-363-3971
F +31-50-363-3800
E j.a.perez@rug.nl

Nijenborgh 9
9747 AG
Groningen
The Netherlands

www.jperez.nl

VERSEN Thesis Award Committee

Date
February 5, 2025

Subject
Nomination Bas van den Heuvel's PhD Thesis

Dear colleagues,

It is my great pleasure to nominate the PhD thesis of my student **Bas van den Heuvel**, entitled "Correctly Communicating Software: Distributed, Asynchronous, and Beyond", to the VERSEN PhD Award. Bas successfully defended his thesis on April 2, 2024.

Bas's thesis studies the rigorous specification, analysis, and verification of the *message-passing* programs that enable distributed software components to seamlessly coordinate. Message-passing programs are notoriously hard to get right: communication-related errors—ranging from message mismatches (e.g., ill-formatted data) and out-of-order messages to race conditions and deadlocks—abound in real-life codebases. Developing techniques for ensuring that message-passing programs always operate correctly is crucial but also challenging.

To rise to this challenge, Bas employs a technical approach in which *process calculi* act as formal languages for specifying communicating programs and *session types* express intended communication structures. Session types are abstractions of the *protocols* that channels in a program are expected to follow; this makes them a convenient instrument for devising both static and dynamic verification techniques for processes. Originated within Concurrency Theory, session types are rapidly making their way into mainstream programming languages, such as Rust and Go; they can specify realistic scenarios involving both binary (two-party) and multiparty protocols and enforce strong forms of communication correctness. Session types are particularly pleasant from a foundational perspective, as they are now known to be in a strong correspondence (in the style of Curry-Howard) with Girard's *linear logic*, the well-known logic of computational resources.

In this context, the thesis targets the following research question:

> How can we push the boundaries of the logical foundations of session types (binary and multiparty), extending their expressiveness and applicability, while preserving fundamental correctness properties?

Bas's thesis tackles this question by offering contributions organized in three distinct parts. The *first part* concerns asynchronous processes with protocols governed by binary session types; the *second part* addresses correct translations of core functional languages into processes; the *third part* develops a new analysis for multiparty protocols that reuses techniques for binary ones.

The number and significance of technical contributions in each part is considerable; it easily goes beyond the average PhD thesis. For the sake of conciseness, I highlight only two of them:

- In Part I, Chapter 2 introduces APCP, a process calculus that accounts for asynchronous communication, whose type system enforces deadlock freedom for cyclic process networks. This combination is highly original, as previous works focus on the simpler setting of synchronous communication with tree-like process networks. Ensuring deadlock freedom by typing for cyclic process networks is technically challenging, as APCP includes also recursion constructs. APCP thus amalgamates principles that ensure considerable expressivity and strong correctness properties. The results that Bas obtained on APCP are impressive on breadth and depth; they are fully developed in a journal paper in *Logical Methods in Computer Science*, which appeared shortly after Bas's graduation ceremony.
- In Part III, Chapter 10 develops a dynamic verification approach to the analysis of multiparty protocols implemented via "blackboxes", software components whose exact behavior is not known. This development is extremely relevant, as communicating components in practice are intrinsically heterogeneous and often not amenable to static verification. The interesting thing is that Bas's technique for dynamic verification is actually an insightful adaptation of a *static* verification approach, which he develops in Chapter 9. Not only: in the context of a BSc thesis that Bas supervised, he developed a practical verification toolkit that validates his approach. This work demonstrates Bas's independence and creativity; it was presented in the International Conference on Runtime Verification (RV); a journal version of the paper was invited to the special issue devoted to best papers of the conference, and is currently under evaluation.

In his thesis, Bas demonstrates a remarkable mastery of foundational concepts in concurrency theory, process calculi, programming languages, and formal methods. Even in his developments of sophisticated programming models, there is also a sharp and evident interest in the potential applicability of theories and in the possibility of verifying realistic scenarios in them.

The substantial significance of Bas's PhD work has been recognized by the assessment committee: Marieke Huisman (University of Twente), Alexander Lazovik (University of Groningen), and Nobuko Yoshida (University of Oxford). The results in Bas's thesis have appeared in high-quality conferences and journals: in addition to the two papers mentioned above, Bas published papers in *Science of Computer Programming*, *Mathematical Foundations of Programming Semantics (MFPS)*, the *Asian Symposium on Programming Languages and Systems (APLAS)*, and *OOPSLA*. Moreover, a paper that was developed during Bas's research visit to Carnegie Mellon University in 2022 (not included in the thesis), appeared in *ECOOP 2024*.

All in all, I am convinced that the PhD thesis of Bas van den Heuvel is fully deserving of the VERSEN PhD Award: it is an exceptional body of work that develops a wide variety of technical results on concurrency and formal methods, which are comprehensive in both depth and breadth.

Yours sincerely,

Prof. dr. Jorge A. Pérez
Associate Professor
Leader, Fundamental Computing Group
University of Groningen, The Netherlands