Asynchronous Programming in the Abstract Behavioural Specification Language

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Contents

Prologue

This manuscript studies the Abstract Behavioural Specification (ABS), a formal language for designing executable models of parallel and distributed object-oriented systems [48]. ABS is defined in terms of a formal operational semantics which enables a variety of static and dynamic analysis techniques for ABS models, e.g., deadlock detection [14, 39], verification [30] and resource analysis [5].

The overall goal of this thesis is to extend the asynchronous programming model and the corresponding analysis techniques in ABS. Based on the different results, the thesis is structured as follows: Part I gives a preliminary overview of the ABS. In part II, we apply an extension of ABS with a notion of shared memory which preserves encapsulation to a case study, where we provide a parallel and distributed model of *preferential attachment* which is used to simulate large-scale social networks with certain mathematical properties. Encapsulation is preserved by a single-write policy. In Part III, we formally extend ABS to enhance both asynchronous programming by data streaming between processes, and parallelism by multi-threading within an actor. Finally in part IV, a new technique based on predicate abstraction is introduced to analyze the ABS models for the absence of deadlock within an actor.

Validation. This work has been carried out in the context of the UpScale Project, an EU-funded project where the vision was:

> to provide programming language support to efficiently develop applications that seamlessly scale to the available parallelism of manycore chips without abandoning the object-oriented paradigm and the associated software engineering methodologies.

In particular, the above extension of ABS concerning streaming of data has been validated by the case study on *preferential attachment* for the efficient multicore and distributed simulation of large-scale social networks. The results of this thesis have been separately validated by the peer-reviewed scientific publications listed in Table 1.

Table 1: List of publications used in the thesis.

Publication	Chapter
Azadbakht, Keyvan, et al. "A high-level and scalable approach for generating scale-free graphs using active objects." Proceedings of the 31st Annual ACM Symposium on Applied Computing. ACM, 2016.	2
Azadbakht, Keyvan, Nikolaos Bezirgiannis, and Frank S. de Boer. "Distributed network generation based on preferential attachment in ABS." International Conference on Current Trends in Theory and Practice of Informatics. Springer, Cham, 2017.	3
Azadbakht, Keyvan, Nikolaos Bezirgiannis, and Frank S. de Boer. "On Futures for Streaming Data in ABS." International Conference on Formal Techniques for Distributed Objects, Components, and Systems. Springer, Cham, 2017.	4
Azadbakht, Keyvan, Frank S. de Boer, Nikolaos Bezirgiannis, and Erik de Vink. "A formal actor-based model for streaming the future." Science of Computer Programming 186 (2019): 102341.	4
Azadbakht, K., Frank S. de Boer, Vlad Serbanescu. "Multi-threaded actors." In: Proceedings 9th Interaction and Concurrency Experience, ICE 2016, Heraklion, Greece, volume 223 of EPTCS, pp. 51–66 2016.	5
Azadbakht, Keyvan, Frank S. de Boer, and Erik de Vink. "Deadlock Detection for Actor-Based Coroutines." International Symposium on Formal Methods. Springer, Cham, 2018.	6