Reserach-proposal

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Abstract

This paper describes the idea, aim and impact of the PhD study do be undertaken.

1 Introduction

Agent-Based Modelling and Simulation (ABM/S) is still a young discipline and the dominant approach to it is object-oriented computation. This thesis goes into the opposite direction and asks how ABM/S can be mapped to and implemented using pure functional computation and what one gains from doing so. To the best knowledge of the author, so far no proper treatment of ABM/S in this field exists but a few papers which only scratch the surface. The author argues that approaching ABM/S from a pure functional direction offers a wealth of new powerful tools and methods. The most obvious one is that when using pure functional computation reasoning about the correctness and about total and partial correctness of the simulation becomes possible. Also pure functional approaches allow the design of an embedded domain specific language (EDSL) in which then the models can be formulated by domain-experts. The strongest point in using EDSL is that ideally the distinction between specification and implementation disappears: the model specification is then already the code of the simulation-program. This allows to rule out a serious class of errors where specification and implementation does not match, which is especially a big problem in scientific computing. The application will be in the field of agent-based computational economics (ACE) where the primary goal will be to implement a pure functional framework with a suitable EDSL in Haskell. This will give computational economists a tool to formulate their models in this EDSL and run them directly in Haskell.

2 Project-Plan

2.1 Years

The whole PhD lasts for 3 years and thus I will structure it according to 3 years where each year will be a major milestone - which is also intended by the Computer School.

2.1.1 1st Year: Basics

In this year I will learn basics and develop and research the methodology I will use for the main work in the 2nd year. Also I want to write 2 papers, see below.

- Prototyping in Haskell, Scala and Java
- Study Actor-Model theory
- Learn how to do reasoning about programs
- Basics of Type- and Category-Theory
- Basics of Economics [3], [6], [1]
- Basics of ACE: [5], [4]
- Write the 2 papers
- Write 1st year report

2.1.2 2nd Year: Main Work

Applying 1st year results, methods and experiences to develop and write main paper to be published in a journal in 3rd year thus in 2nd year the main work and implementation will be done. The idea is to start from Ionescus Framework [2] and build on his paper.

- Implement Ionescous framework using the methodology developed in 1st year
- Generalize implementation to market models
- Learn Agda and dependent types
- Category Theory
- Type Theory

2.1.3 3rd Year: Finalizing, Publishing & Writing

I plan to be finished - or nearly finished - at the end of the 3rd year. In this year I will finalize the work of the 2nd year, publish the my main journal paper (and optional fun-papers if possible) and will write down the thesis.
To have a bit of distraction and to prevent myself to become too locked in in writing on the thesis I will also work on my optional fun-papers (see below) and hope to at least finish them and maybe publish them - at least I want to present them to 2-3 audiences (e.g. FP Lunch) to test the reaction (especially the Genesis-Paper).

- Finalize research of 2nd year

- Publish journal paper
- Write thesis
- Work on fun-papers

2.2 Papers

This is the list of papers I want to work on. The goals of publishing I set for myself are given beside the paper.

1. *Pure by Nature: Agent-Based Simulation & Modelling in Haskell* - Conference paper
2. *Actors: The Future in Agent-Based Simulation & Modelling?* - Conference paper
3. *Pure Functional ACE (Catchy title yet to be defined)* - Journal paper
4. *The Genesis According to Computer-Science: Reality as Simulation of Free Will* - Optional publishing
5. *Pure Functional Islamic Design* - Optional publishing

2.2.1 Pure by Nature: Agent-Based Simulation & Modelling in Haskell

The first paper which describes how one can implement ABM/S in Haskell and compares the implementation and results to Java and Akka. A major focus are update-strategies, parallelism, reproducibility, reasoning and comparability between the various implementations. Multiple approaches are shown in Haskell: no framework, Yampa-based, gloss-based, ?-based. This paper will establish my methodology in using Haskell / pure functional programming in the 2nd year main work.

2.2.2 Actors: The Future in Agent-Based Simulation & Modelling?

Although the actor-model is quite old (beginning of the 70s) it seems to have a revival both in Erlang in the 90s and now in the Framework Akka (based on Scala). It is one way of organizing highly parallel (and optionally distributed) applications. Also the actor-model is very close to the agent-metaphor where the latter one was strongly inspired by the former one. Thus It would be very interesting to look closer into how the Actor-Model can be utilized to ABM/S as it seems that this has not been properly done yet.

2.2.3 Pure Functional ACE (Catchy title yet to be defined)

Is the main work of the PhD and targeted at publication in a Journal. The exact topic and content will be clarified at the beginning of the 2nd year. Mainly it will describe how to implement Ionescus Framework of Gintis trading model and extend it to a more general Market-Model. It will also give an outlook on implementing it using dependent types.

2.2.4 The Genesis According to Computer-Science: Reality as Simulation of Free Will

I've always been interested in a deeper meaning behind things so I want to look into the philosophy and future of simulation: why do we simulate, what can we derive from simulations, what does it say that we humans simulate, what will the future of simulation be?
I claim that our ability to "simulate" in our mind separates our intelligence from those of the animals and that this is a unique property of humans. Also i think the future of simulation will be that humankind will do its own creation/live (artifical life, conciousness) which allows to accurately simulate a given setting - this of course could have ethical implications.
This is fun paper 1.

2.2.5 Pure Functional Islamic Design

Inspired by the paper "Functional Geometry" by Peter Henderson I had the idea to come up with a EDSL for declaratively describing pictures of islamic design which are then rendered using the gloss-library.
This is fun paper 2 - from its focus totally unrelated to the PhD topic but still a great opportunity to learn Haskell, to learn to think functional, to learn to design my own EDSL - thus it may be a great paper to pursue even if I won't finish or produce something publishable.

References

[1] Baker, H. K., Kiymaz, H., Alan, N. S., Bildik, R., and Schwartz, R. Market Microstructure in Emerging and Developed Markets. *Business Faculty Book Gallery* (Jan. 2013).

[2] Botta, N., Mandel, A., Ionescu, C., Hofmann, M., Lincke, D., Schupp, S., and Jaeger, C. A functional framework for agent-based models of exchange. *Applied Mathematics and Computation 218*, 8 (2011), 4025 – 4040.

[3] Bowles, S., Edwards, R., and Roosevelt, F. *Understanding Capitalism: Competition, Command, and Change*, 3 edition ed. Oxford University Press, New York, Mar. 2005.

[4] Darley, V., and Outkin, A. V. *Nasdaq Market Simulation: Insights on a Major Market from the Science of Complex Adaptive Systems*. World Scientific Publishing Co., Inc., River Edge, NJ, USA, 2007.

[5] Kirman, A. *Complex Economics: Individual and Collective Rationality*. Routledge, London ; New York, NY, July 2010.

[6] Lehalle, C.-A., and Laruelle, S., Eds. *Market Microstructure in Practice*. World Scientific Publishing Co. Pte. Ltd., 2013.