

SICSA Distinguished Visiting Fellowship — Final Report

Visitor: Dr Janis Voigtländer, Universität Bonn (formerly of TU Dresden)

Principal Investigator: Dr Patricia Johann, University of Strathclyde

Co-investigator: Prof Alex Simpson, University of Edinburgh

Dr Janis Voigtländer visited Scotland from 5 to 13 March 2009, from 19 to 30 April 2009, from 24 August to 5 September 2009, and then again from 20 to 26 April 2011. This report summarizes the activities and scientific progress achieved during the visits.

During Dr Voigtländer's first visit to Scotland, he gave a CIS departmental seminar entitled "Type-based Reasoning and Imprecise Errors" at the University of Strathclyde on 6 March 2009. Slides are at

<http://www.iai.uni-bonn.de/jv/glasgow-slides.pdf>

This seminar attracted about 15 people and was particularly well attended by researchers at the University of Strathclyde, including several newly arrived PhD students. It served as a good introduction to the parametricity research previously conducted by Dr Voigtländer and Dr Johann during the five years previous to the visit.

During Dr Voigtländer's second visit to Scotland, he gave a LFCS seminar on applications of parametricity to the problem of semantic bidirectionalisation at the University of Edinburgh. It was held on 21 April 2009 and attracted about 20 people; the slides are at

<http://www.iai.uni-bonn.de/jv/edinburgh-slides1.pdf>

During this visit, Dr Voigtländer also gave a short course for graduate and postgraduate students called "Free Theorems and Applications". The short course was held at the University of Edinburgh on 22, 23, and 24 April, and comprised three interconnected talks on the foundations of free theorems, their application to Knuth's 0-1 principle and related problems, and their extension to "real" programming languages. Free theorems describe the behavior of polymorphic functions that can be derived solely from their types. They are consequences of Reynolds' seminal theory of parametricity, which formalizes what it means for a function to provide common functionality at different types. While Reynolds' theory was originally developed for the pure polymorphic lambda calculus, Dr Voigtländer's talks centered on extensions of the theory of parametricity to accommodate constructs found in more realistic programming languages. The talks attracted about 10-15 researchers per lecture from SICSA member institutions. Slides are at

<http://www.iai.uni-bonn.de/jv/edinburgh-slides2.pdf>

<http://www.iai.uni-bonn.de/jv/edinburgh-slides3.pdf>

<http://www.iai.uni-bonn.de/jv/edinburgh-slides4.pdf>

Dr Voigtländer's third visit to Scotland was divided between the SICSA International Summer School on Advances in Programming Languages, held from 25 to 28 August 2009 at Heriot-Watt University, and the 2009 International Conference on Functional Programming (ICFP'09), held from 31 August to 2 September in Edinburgh. At the former, Dr Voigtländer gave a talk entitled "News About a Recent Application of Parametricity", whose slides are at

<http://www.iai.uni-bonn.de/jv/aip12009-slides.pdf>

At ICFP'09, he presented his paper "Free Theorems Involving Type Constructor Classes". The slides from this talk are available at

The SICSA summer school was well-attended by about 45 European researchers, and ICFP had its customary international draw of between 200-300 participants. Many of these came from SICSA institutions.

It was originally expected that Dr Voigtländer's final visit to Scotland would be in the summer of 2009. But his move from a postdoctoral research position at TU Dresden to a new lectureship at Universität Bonn, and some difficult personal circumstances of Prof Simpson, caused repeated delay of the visit. Then Prof Simpson was on sabbatical in Slovenia during the entire 2010-2011 academic year. Ultimately Dr Johann and Dr Voigtländer decided to meet in Prof Simpson's absence just to move the research along. The three of us had just met to discuss our work while attending the European Workshop on Computational Effects (organised in part by Prof Simpson) in Ljubljana, and we wanted to meet shortly thereafter to take advantage of momentum generated in those discussions.

During all his visits, Dr Voigtländer met for extensive research meetings with Dr Johann and Prof Simpson. The research questions considered were exactly those mentioned in the SICSA DVF proposal, namely how to construct a theory of parametricity which is both based on operational semantics and uniformly instantiable to specific languages of interest. The languages we considered are call-by-name ones that support those computational effects that can be modelled by the algebraic operators of Plotkin and Power. Our research meetings were very stimulating and fruitful and have had significant concrete outcomes. In particular, they are directly responsible for our joint paper *A Generic Operational Metatheory for Algebraic Effects*, which was accepted for presentation at the 2010 IEEE Symposium on Logic in Computer Science (LICS'10). LICS'10 was held in Edinburgh as part of the Fifth Federated Logic Conference (FLoC'10). Unfortunately, Dr Voigtländer was unable to attend LICS'10, but the talk delivered by Prof Simpson was attended by a significant number of FLoC'10 attendees, who were able to move freely between its 8 major conferences and 48 associated workshops.

As far as we know, our results reported at LICS'10 constitute the first to attempt a systematic operational metatheory that applies to the setting of functional languages with effects. To obtain them, we combined two previously distinct research areas: Plotkin and Power's theory of algebraic effects and Pitts and Stark's logical-relation-based approach to operational reasoning. Although our results have thus far been obtained only for call-by-name languages, we believe it will be possible to adapt our methods to obtain similar ones in the call-by-value setting. Extending the LICS'10 work to call-by-value languages, which provide a more natural home for effectful computation than call-by-name ones, is work in progress. So is preparation of a journal version of our LICS'10 paper.

Indeed, we envision our LICS paper as just the start of an entire line of research jump-started by this SICSA DVF. Although our results cover algebraic effects and the combinations of specific such effects, we would like to establish that the sum and tensor operations for combining Lawvere theories correctly account for the principal examples of combinations of algebraic effects, and that they have analogues in our operational setting. Moreover, our current theory does not cover all effects that have been described as "algebraic" in the literature — for example, it does not cover countable nondeterminism, local state, or global or local store — so extending our results to accommodate these effects is a promising direction for further research. Finally, we hope to extend our theory to allow effect operations that are blatantly non-algebraic, such as exception handlers and other control primitives. We expect that, with Prof Simpson back in Edinburgh from the end of the summer, our joint research should pick up again and this should lead to significant new developments in the coming months.