MENTORING AFRICAN RESEARCH IN MATHEMATICS

FINAL REPORT

Any photos of the partnership would be welcomed for use by the LMS and IMU CDC for their publicity materials. Please send these to Katy Henderson (marm@lms.ac.uk)

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Review of second year of partnership
Please comment on:
1. *Any visits made in the second year: a) the aims of the visits; b) activities undertaken as part of the visits; c) objectives achieved by the visits.*

The main activity of the grant in 2016 was the **Second Nairobi Workshop in Algebraic Geometry in July 2017**, built around two-week visits to UoN by Prof Miles Reid FRS and Professor Gavin Brown of the University of Warwick, and two of their graduate students. The aim of the workshop was to provide training in certain topical areas of algebraic geometry to the African participants, and to give an opportunity to local researchers to present their work. The full list of participants of the workshop was as follows:

Miles Reid, Gavin Brown, Enrico Fatighenti and Sara Muhvic (University of Warwick), David Ssevvirrii, Bazeyo Edson and Innocent Ndikubwayo (Makerere University) Abera Muhamed (Ethiopia), Claudio Achola, Jared Ongaro, Ben Kikwai and Damian Maingi (University of Nairobi), Ben Obiero (Technical University of Kenya), and about 15 Masters and PhD students of the University of Nairobi.

Gavin Brown gave introductory lectures on graded rings in algebraic geometry. Miles Reid gave a course of seven 90-minute lectures, covering basic material of Algebraic Geometry, leading up to an almost complete treatment of Riemann-Roch for curves. Enrico Fatighenti gave two lectures on

Hodge theory for algebraic manifolds, esp. hypersurfaces and Griffiths residues. Sara Muhvic lectured on quotient singularities and their resolutions. They both discussed extensively with the Masters students, in support of the main lectures.

One outcome of the visit was to help the UK visitors appreciate the difficulties involved in teaching science in an African environment, such as the scarcity of resources in terms of teachers, money, lecture rooms and admin help, and in particular the very heavy teaching loads.

Another outcome was that Miles Reid put David Ssevviiri in touch with Michael Wemyss (University of Glasgow), as a consequence of which they won an LMS grant for David to visit the UK in May 2017.

A research visit was made **by Prof Laura Costa** (Universitat de Barcelona) to the University of Nairobi **in December 2016**. The aim of the visit was to explain and propose to the algebraic geometry group in Nairobi problems concerning vector bundles on algebraic varieties, mainly on algebraic surfaces. To do so, Prof costa gave an introductory course on vector bundles on algebraic surfaces focusing attention on the background needed to introduce the problems (vector bundles, cohomology, notion of stability, moduli spaces, change of polarization, geometrical properties of moduli spaces, rationality, ACM and Ulrich condition). Lecture sessions were complemented by discussion sessions. Prof Costa provided also a list of research question that the local researchers can feasibly work on.

   2. *Any other activities undertaken during the year: a) the purpose of these activities; b) the objectives achieve by these activities.*

Besides the Second Workshop and Prof Costa's visit to Nairobi, the grant also supported Mr Elvice Ongonga's PhD application. Elvice had completed a Masters in Algebraic Geometry in the Nairobi group. He was shortlisted for a PhD scholarship by the EU-funded ARCADES network working on algebraic representations of complex shapes in computer-aided design. He was invited to Vienna to attend a workshop of the network in April 2016, and to present a poster on his Master's thesis. While he was not successful in obtaining the scholarship, he gained valuable international experience at the workshop. He is now applying for a "sandwich" PhD Programme as part of the EAUMP (Eastern African Univesities Mathematics Programme) PhD scheme.

Dr Jared Ongaro from the Nairobi group visited the University of Oxford in Jan-Feb 2016, and the University of Sheffield in March-April 2016. While no funds from the current grant needed to be used, this visit can also be seen as one of the activities of the partnership. Research projects have been started with Prof Szendroi in Oxford and Dr Paul Johnson at Sheffield.

A small part of the grant was used to purchase books for the Nairobi group, including Harris: Algebraic geometry, Fulton-Harris: Representation theory, and Cavalieri: Algebraic curves and Hurwitz theory.

All these activities were aimed at strengthening the algebraic geometry group. Successes are noted in the next section.

Review of the partnership as a whole
1. *Please comment on the progress of the partnership across the two years of the project. Please include any significant achievements made during the course of the project; any particular difficulties met and how these were addressed; any lasting changes that were achieved for the department; any other comments.*

The aim of the Partnership has been to support the Algebraic Geometry group at the University of Nairobi. This research group is one of the most active groups in pure mathematics in East Africa, engaged in Masters and PhD training, research-level publishing, and organizing research activities.

A large proportion of the funds were used to run two workshops in Algebraic Geometry, with a varied cast of visitors including, apart from the grant holders Prof Szendroi and Brown, also Prof Cavalieri from Colorado State Univerity, Miles Reid FRS from the University of Warwick, postdocs and PhD students from various universities in Europe, as well as African researchers from Kenya, Uganda, Nigeria, Congo and Ethiopia. Beyond the mathematical content, which was certainly substantial, it is hoped that the Workshops will help in creating a network of researchers interested in Algebraic Geometry and related fields around the African continent. One outcome of the grant is a web-based database of such researchers, built by Dr Jared Ongaro, available at

    https://profiles.uonbi.ac.ke/ongaro/links/african-algebraic-geometers

The workshop series will continue; there will be a small-scale workshop built around Prof Szendroi's visit to UoN in June 2017, and there are well-established plans to run a larger workshop again in Summer 2018.

One of the important events that happened during the lifetime of the grant is a planned third appointment in Algebraic Geometry at the University of Nairobi. Alongside Dr Maingi (recently promoted to Senior Lecturer) and Dr Ongaro (Lecturer), Dr Ben Kikwai will soon be appointed (funds permitting) as Lecturer. Dr Kikwai received his PhD in June 2016 at ICTP under the supervision of Prof Lothar Gottsche. His external examiner was Prof Szendroi. While the grant played no concrete role in this potential appointment, the Head of Department, Prof Patrick Weke, is a frequent guest at the grant Workshops and the international visibility of the group has likely contributed to the support shown to it by the Department.

Another substantial milestone was the first award of a "home-grown" PhD in Algebraic Geometry at the University of Nairobi, under the research supervision of Dr Maingi. Dr Ben Obiero completed a thesis entitled *On the minimal resolution conjecture for the ideal of general points in the projective space P^4*. Ben participated at both the 2015 and the 2016 Workshops. His PhD examiner was Prof Costa; the defence took part during Prof Costa's visit in December 2016.

The group produces a regular stream of competent Master students (see below for a list). To develop further, it would be essential for some of these students to get access to international PhD opportunities. During the lifetime of the grant, two students (Elvice Ongaro, Ambrose Mwangi) submitted applications for a variety of positions, but none of these was successful. This remains an unresolved problem.

In summary, it can be stated that the Algebraic Geometry group is in a relatively healthy state compared to other pure math research groups on the continent, but it will need further support. MARM has been very helpful in providing a solid base for the activities for two years; the grant holders plan to apply for different sources of funding moving forward.

Appendix: list of Masters theses in algebraic geometry completed during the life-time of the grant

- Deborah Opollo, 2014, *On abelian sandpile model of a directed multi-graph,* advisor Damian

Maingi
- Elice Omondi Ongong'a, 2015, *Enumeration of plane rational curves,* advisor Jared Ongaro
- Ambrose Mwangi, 2015, *Classification of cyclic surface singularities,* advisor Jared Ongaro
- Ignace Ntezimana, 2016*, Combinatorics of Hurwitz numbers,* advisor Jared Ongaro
- Patrick Omukuba, 2016, *Topology of the Hilbert scheme of points in the plane*, advisor Jared Ongaro