Maths Matters

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KEY MESSAGES

- Maths is not just about algebra and trigonometry: it is a vibrant and rapidly developing fundamental science which frequently delivers ground-breaking discoveries.
- Maths research underpins other research across the sciences and has myriad and surprising applications, including biology, engineering, finance, and security at GCHQ. It thus delivers numerous benefits to the UK and globally, including impact in the health, economic and social sectors.
- It is therefore important that mathematics research is fully valued as a crucial part of the UK's research environment and that policy and funding decisions reflect this.

Introduction

Research in mathematics is vitally important in its own right and in terms of its contribution to other disciplines. It offers a way of understanding fundamental questions about our world, and delivers high-impact applications. Mathematics can model how the world works and helps us to understand how social, economic, natural and industrial systems operate. It provides a language and tools with which to understand science, and underpins research in science and engineering and technological development, from systems biology, to MRI, to bridge-building. Maths also has the unique ability to study problems in the 'abstract'; namely without a specific application. The same mathematical techniques can thus be used in diametrically opposite contexts: for example, the same maths can be used to help study the fundamental particles in nature and the hulls of submarines.

UK mathematics research outperforms the world average in terms of citation impact and has seen its performance grow in the past 2 decades [1] This research performance is matched by the contribution that maths research makes to society, as can be seen from this briefing. UCL Mathematics and Statistics received around 3.6% of total national funding in 2012 and was the 3rd largest recipient of funding per FTE [2]. UCL mathematics research performed well in the 2008 RAE, with 60% of our pure maths and 50% of our applied maths submission being rated internationally excellent or world-leading. Of the 6 British winners of a Fields medal, 3 were former staff member of UCL mathematics.

UCL research in mathematics is highly diverse and has close connections with a variety of other scientific disciplines, being actively involved in cross-disciplinary collaborations across UCL. The following examples provide a flavour both of the strength and depth of UCL maths research as well ask its benefits and importance to our society and economy.

Modelling the brain

The human brain is highly complicated, and keeping it healthy is one of the foremost medical challenges. In **CoMPLEX** at UCL, mathematicians and physical scientists work on challenges arising from complexity in biology and medicine. In particular, **mathematics is vital for understanding how reactions in the brain evolve and interact**, bringing us closer to deciphering the complexity of the human brain.
For example, mathematicians are developing a **model of the brain of newborn infants** to investigate the effects of the reduction of blood flow or oxygen supply on the brain. This can often result in severe disabilities, such as cerebral palsy. Mathematicians are working closely with engineers and clinicians to enable informed, practical and translatable predictions about patient outcome and clinical strategies that can be used. The ultimate aim is to develop a clinical tool, incorporating the mathematical model, which can be used at the bedside to provide clinicians with a better understanding of the cerebral health of the patient.

Aircraft safety

We are all travelling more often by air and the issue of aircraft safety continues to regularly make the headlines. When an aircraft flies through cloud at or below freezing temperature, ice can form on its forward-facing parts: this can lead to detrimental performance, and has been a significant factor in a number of past incidents and accidents, some of which resulted in the loss of life. Researchers in UCL's Department of Mathematics, led by **Professor Frank Smith**, investigated and modelled various situations of relevance to aircraft icing, ensuring that models are realistic.

AeroTex used these research findings to design **new and improved ice protection systems for fixed wing or rotor aircraft**. These new designs enabled aircraft manufacturers to comply with upcoming changes that are raising aircraft certification standards and to operate aircraft more safely in icing conditions.

Tackling noise

Noise caused by cars, trucks and airplanes has become a nuisance to most of us. Various agencies, from policy makers to aircraft engineers, are seeking to combat the impact of noise, particular on communities residing in the vicinity of freeways, airports and wind turbine farms. **Dr Nick Ovenden** at UCL, together with collaborators, developed **mathematical techniques to assess the impact of these strategies**, leading to commercial, environmental and public health benefits internationally.

For example, traffic noise modelling for Arizona Department of Transportation has led to changes in their approach to noise mitigation strategies as well as informing public and policy debate elsewhere. In addition, Liebherr Aerospace has used the mathematics research to test designs to reduce noise from aircraft engines.

The trading dark pool

Financial trading has become one of the cornerstones of the UK economy, but with the rise of computer-based trading the world of finance is changing rapidly. There is now a hidden trading point called the dark pool where computer-based high-speed algorithmic trading has only recently been allowed. Here, trades occur in secret: sellers put up stock, buyers put up offers, and they are matched anonymously.

UCL mathematicians are looking at the **financial consequences of different possible policies that regulators could enforce on the dark pool**. Would putting up a fee for dark pooling reduce the competitiveness of the dark pool and encourage more deals in the open market? Would it be beneficial to have to alert the open market before a deal is done, increasing information available to everyone? These sorts of important policy-making questions are being answered right now by sophisticated computer simulations at UCL.

Google Translate

Google Translate is a fast translation tool on the internet. The method previously used by Google Translate required huge amounts of information to be physically stored on a massive number of computers. Research at UCL by **Dr John Talbot** was applied to store the information concisely using randomness, thus greatly **reducing the amount of storage space** required. The research used sophisticated methods of probability and counting arising from abstract mathematical problems, which can now potentially be used in a variety of settings.

Our society: from riots to globalization

Recent advances in complexity science and the mathematical modelling of social systems present new opportunities in addressing the real-world problems of concern to policy makers. This emerging field, at the interface between the social sciences and mathematics, has the potential to provide a greater understanding of our society, and assist in designing better systems for all: from healthcare services to transport and policing.

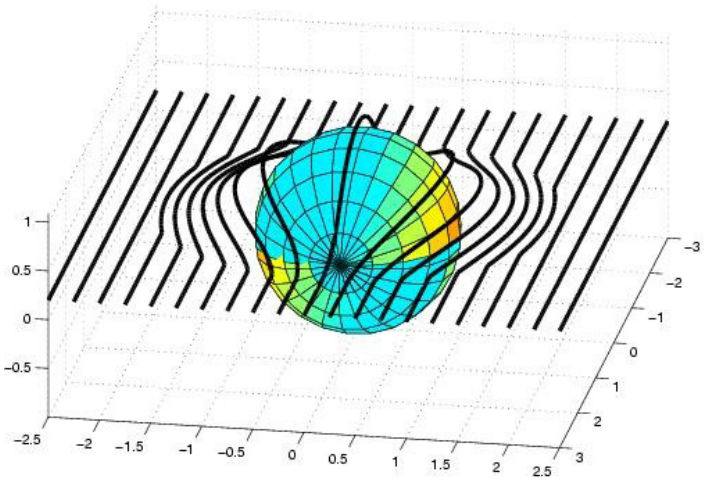
UCL mathematics has recently developed a number of interdisciplinary projects in this area. A paper published in Nature's Scientific Reports exploits the mathematical patterns in the London riots of 2011 to demonstrate why **some areas of the city were at a higher risk than others** and give quantitative insights into which policing strategies may have resulted in a swifter resolution to the unrest. Follow-up projects to this work include a short film and video game simulation which have received a good deal of media attention online, in press and on national television, serving to raise awareness, improve understanding and prompt public debate about the riots, the role of youth charities in London and the **potential use of mathematical modelling to address questions about the UK's social systems.**

In addition, UCL mathematicians have worked with the police to examine the nature of burglaries; with UCL Crime Science to understand the **dynamics of conflict in Korea**; and with economists and geographers on EPSRC's ENFOLD project to understand the **interdependence of global trade and migration flows**.

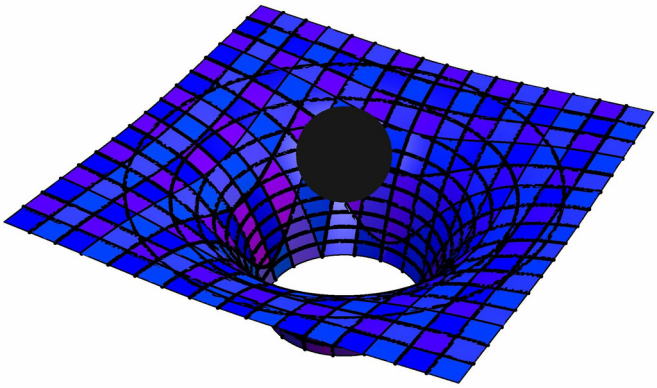
Cloaking

Cloaking devices sound like something out of science fiction or fantasy, but mathematics has helped towards making this seeming impossibility into reality. **Professor Yaroslav Kurylev** at UCL was part of team of mathematicians who investigated the method of **bending light waves around an object to create an "invisible" space** which is cloaked. This led to interesting mathematical phenomena, including the possibility of an "electromagnetic wormhole": an invisible tunnel between two points through which electromagnetic waves like light could be sent without detection.

Potentially, cloaking using these electromagnetic wormholes could be used to create invisible fibre optic cables, for example for security, and medical probes during MRI procedures for which metal tools would otherwise interfere with the scanner.



Light rays bending around a 'cloaked' object



Different behaviours of gravity in a black hole

Origins and evolution of the universe

UCL's **Institute of Origins** was created to promote world-leading research into the Origins and Evolution of the Universe, the basis of life and how we came to exist. The Institute researches topics spreading in scale from the microscopic to the cosmological, incorporating researchers from mathematics, physics, astronomy and earth sciences.

In particular, **Dr Christian Boehmer** is using ideas from material sciences to create a **new mathematical theory of gravity**, which is still one of the greatest mysteries in science. This includes investigating the possibility that the vacuum could be a crystal and has led to new models of black holes.

[1] International Comparative Performance of the UK Research Base - 2011: a report prepared for the Department of Business Innovation and Skills. Elsevier: 2011; field-weighted citation impact for UK and comparators across ten research fields in 1996-2000 and 20006-2010].

[2] Source: HESA

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