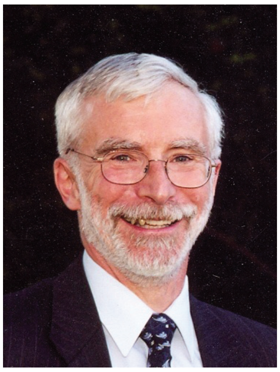
Mathematics research – why is it important? And the IMA – what is it for?

In 2014 the Institute of Mathematics and its Applications (IMA) celebrates its 50th anniversary. We will describe what the IMA has done later in the article, but first we want to address a bigger question: why is mathematics research important to the UK?



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We start with some numbers. In 2012 Deloitte, commissioned by the EPSRC and the Council for Mathematical Sciences[1] (CMS), completed an analysis[2] of the effects of mathematics research on the UK economy. Their conclusions are striking. In 2010, mathematics research directly contributed 2.8 million jobs and £208 billion in Gross Value Added (GVA) to the UK economy (the latter being 16% of the total GVA), spread over a wide range of sectors. There is no surprise that large contributions were identified in banking & finance (£27 billion) and computer services (£19 billion). Perhaps more surprisingly there were almost equally significant contributions to pharmaceuticals (£16 billion) and construction (£13 billion). 80% of all UK jobs in the R&D sector and 50% in aerospace can be identified with the mathematical sciences. These tangible financial effects are matched, or arguably exceeded, by the contributions of mathematics research to the public good, through improved healthcare, national security, the entertainment industry, et cetera.

How does mathematics research have such a large effect on the UK economy and national life? The answer is that mathematics is a ubiquitous part of the physical and virtual infrastructure of the 21st century; it plays a key role in design, manufacturing and optimisation as practised by the whole gamut of UK industry; it underpins uncertainty forecasting and future planning; and it is at the heart of national and cyber security. Let us look at three examples from the last 50 years of mathematics research in action. These are all taken from 'Mathematics Matters', the IMA's recent series of one-page case studies[3].

Internet shopping: stopping the scammers. The dangers of online fraud are well-known to anyone using the internet, but the cost to UK business is enormous (in 2009 £60 million was lost by UK banks in online phishing attacks alone). The secure transfer of data online is done using Public Key encryption, a technique originating in mathematical number theory and developed by the mathematician Clifford Cocks working at GCHQ in 1973. Given that half of UK retail shopping may be done online by 2020, the need for more secure means of data transmission is self-evident. Work by mathematicians on 'unbreakable' quantum codes continues apace[4].

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Advancing the Digital Arts. The UK is a world-leader in computer-generated images and animation for the movie industry. Annual sales by UK companies are at least £375 million. One key mathematical challenge here lies in describing complicated moving objects by using only a limited amount of data (see figure for an example of a mathematically generated object), or in simulating physical phenomena like flowing water or smoke. In the latter case the equations describing a rushing torrent are much too difficult to solve fully, even on the world's largest computers. Part of the mathematician's art is to develop equations which give an answer which 'looks' right to the cinema audience, but is much easier to solve!

Modelling an Epidemic Emergency. In recent years the UK has been hit by a number of major outbreaks, such as the swine flu epidemic in 2009. Nationwide action was supported by mathematicians and epidemiologists working to understand the spread of infection and mitigate its effects.

A key mathematical issue here lies in coping with the large uncertainties inherent in understanding mass social interaction. In 2009, mathematical models were developed from an early stage, and continuously refined as the epidemic progressed and more data became available, allowing realistic forward planning of health services.

least through journal publication and specialist conference organisation, much of which spans the industry-academia interface.

- Policy and public engagement – working with government and research councils to enhance the public profile of mathematics and (applied) mathematical research.

... equations describing a rushing torrent are much too difficult to solve fully ...

We now want to change tack and talk about the Institute of Mathematics and its Applications[5]. The IMA is

"…the UK's learned and professional society for mathematics and its applications. The IMA exists to support the advancement of mathematical knowledge and its applications and to promote and enhance mathematical culture in the United Kingdom and elsewhere, for the public good."

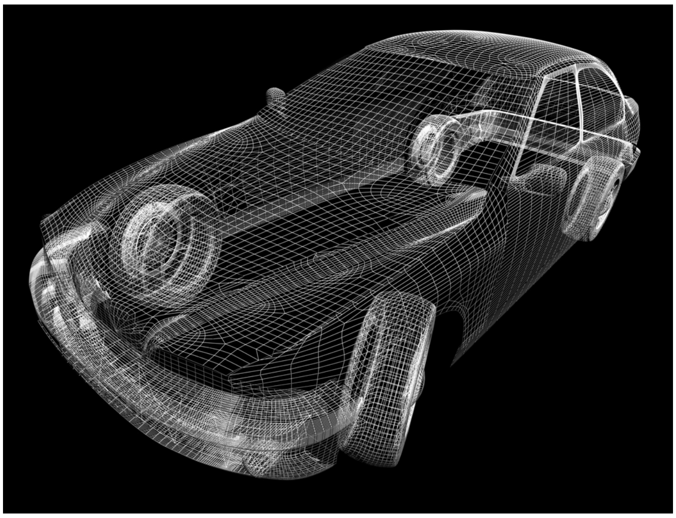
Major activities include:

- Professional affairs – helping companies design graduate training schemes in mathematics and helping individuals with their professional development, culminating in Fellowship of the IMA and designation as a Chartered Mathematician.
- Education, both in schools and in higher education – participating in national mathematical bodies such as the Joint Mathematical Council and the Advisory Committee on Mathematics Education, curriculum design, contributing to the HE-STEM programme, offering the Chartered Mathematics Teacher recognition (instituted in 2008).
- Research – supporting mathematical research in industry and universities, not

Since the IMA was founded, the nature of applied mathematics research has changed a lot. In 1964, most was in areas of classical physics – mechanics (of fluids and solids) and electromagnetism – with practical applications in various branches of engineering, meteorology, astrophysics, etc. There are now many more fields in which mathematics is being applied – biology, chemistry and economics, to name but three. In addition, there have been enormous developments in the mathematics that can be applied – dynamical systems theory and chaos, partial and stochastic differential equations, control theory, optimisation theory, and numerical analysis, which underpins the computing that forms a central part of applied mathematics research today. The development of new mathematics, driven by major applications, will not slow down. Many challenges are brought into being by 'Big Data'; the new fields of compressed sensing and imaging (in which crucial information can be recovered from big data sets using few measurements, and images ranging from home photographs to medical brain scans are analysed and improved[6]) are all cases in point.

The original motivations have not gone away. Virtually every new problem involving the flow of fluids requires new mathematics – not necessarily using new techniques, but needing experience in translating real problems into mathematical form, and being able to derive an appropriate solution. This can only be provided by a good applied mathematician. This brings us to the greatest challenge that we face today: how can we increase the supply of good applied mathematicians?

What is a good applied mathematician? It is someone who knows a lot of mathematics at the appropriate level, but in addition has experience and facility at translating problems from outside mathematics into mathematical form, solving the mathematical problem, and interpreting the answer. It is necessary first to clarify the problem to be translated. Understanding a phenomenon can rarely be achieved by trying to simulate everything about it.



However, it is a common observation that even the brightest students, coming to university from some of the best schools, lack experience of applying mathematics to problems they have not seen before. Part of the trouble is that their teachers don't have this experience either. What is the answer? Anyone planning to teach sixth-form mathematics should be required to practise applying mathematics to something they haven't seen before as part of their training. Such practice should be a central part of mathematics at A-level, not just as part of an easy-to-avoid option; the same should be the case in undergraduate mathematics degrees. With any luck, after a few years our colleagues in industry will have even more reason to hire mathematicians than they have now.

What about the next 50 years? The one thing we can say with absolute certainty is that the opportunities for the application of mathematics will grow and grow, and in the UK we must position ourselves to exploit these opportunities to the full. In doing this the IMA's role in promoting applied mathematics, and in training and supporting the next generation of applied mathematicians, will be crucial.

References

1 CMS is the umbrella body representing the UK learned societies in mathematics. http://www.cms.ac.uk/

2 See http://www.epsrc.ac.uk/newsevents/news/2012/Pages/mathscireesearch.aspx

3 http://www.ima.org.uk /i_love_maths/mathematics_matters.cfm.html

4 http://www.cam.ac.uk/research/news/quantum-sealed-envelope-system-enables-perfectly-secure-information-storage

5 http://www.ima.org.uk/

6 http://www.damtp.cam.ac.uk/research/cia/research/