ncaf Natural Computing Applications Forum

Networks

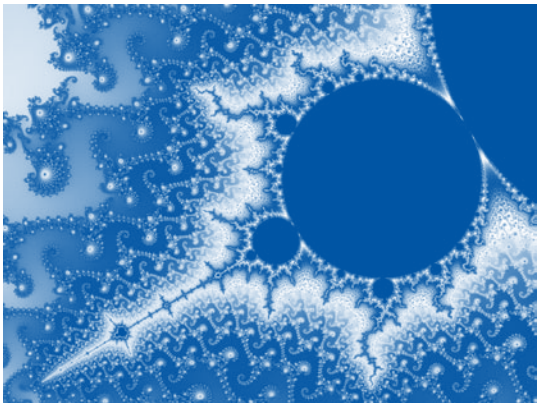
Making Complexity Useful

Aston University, Birmingham, 19-20 January 2010

A key aspect of current research in complexity is to move beyond running simulations and measuring complexity.

The next NCAF meeting will focus on 'Complexity'. A recurring theme in the strategic plans of research councils is the need for principled approaches to dealing with complexity, high dimensionality, high connectivity, heterogeneity, and emergent behaviour in natural and artificial systems. The application domains are very wide ranging, spanning the future internet, agile and distributed sensors and communications, nanoscale manufacturing, social/financial/medical networking, distributive control of transportation (smart cities) and power generation, and global environmental systems. The underpinning science spans non-linear and stochastic mathematics, the physics and biology of open interactive systems, and sociological and anthropological aspects of communities. A key aspect of current research in complexity is to move beyond running simulations and measuring complexity (with Lyapunov exponents and related metrics) to analysing and predicting behaviour: making complexity science useful.

The first day starts with a talk by David Saad (Aston University). Titled 'Probabilistic Approaches to Understanding Complex Systems', it will demonstrate how using a whole-system approach coupled with probabilistic models and reasoning enables us to understand, predict and control the behaviour of complex systems. Other talks that we have lined up will be on communication networks, complexity in economics, and how to measure complexity in biosignals to diagnose health problems.



Wolfgang Beyer

The Mandelbrot set illustrates how the simplest of rules can create patterns of never ending complexity.

On the second day we will have general papers, including a talk on the application of genetic programming to knitting patterns. If you want to find out how to weave that particular tangled web, you will have to be at Aston in January! As for all NCAF events, please register at **www.ncaf.org.uk**.

Prof. Ian Nabney
Aston University

2010 Annual General Meeting

The NCAF AGM will take place during January's event. Topics for discussion include a review of the membership structure, as well as the move to twice yearly meetings. New committee members are always welcome!

DIARY DATES 2009/10

15–17 December – AI-2009, the 29th annual international conference of the BCS SGAI in Cambridge, UK.
http://www.bcs-sgai.org/ai2009/

28 April – ICCMNC 2010, International Conference on Computer Mathematics and Natural Computing, Rome, Italy.
http://www.waset.org/conferences/2010/rome/iccmnc/

July – NCAF meeting (venue and theme TBD).

Grand Challenge

The data explosion and 'Google World' highlights the need for professional consultation with doctors.

May 20th-21st found the NCAF merry band in Swansea once again for a rather special meeting, sponsored by Swansea University and the Engineering & Physical Sciences Research Council (EPSRC). This workshop had the special theme 'Grand Challenges in Information-Driven Health Care' and provided a forum for the seven EPSRC supported Grand Challenge projects funded in March 2008 to explore their respective various Grand Challenge views (see **www.epsrc.ac.uk** for a list of all the projects supported). So in a very dense programme, the majority of the 13 talks over the two days was given over to presentations from each of the projects, combined with an excellent social event and Fenella's controversial 'Puzzle Corner', complete with pantomime camel!

After the opening talk by David Ford of the Health Information Research Unit for Wales, Jason Maude, the CEO of Isabel Healthcare Ltd, began by providing his commercial experience perspective and an emotional motivation for the importance of research into future information-driven health care. His company is addressing the problem of an estimated (and worrying) 20% of patient mis-diagnoses by providing a web-based tool for text natural language processing of some 11,000 diagnoses checks. It is interesting to note that in his view the IT aspect is the easy part; it is the required cultural change that is difficult.

Nic Smith (Oxford University) gave a talk on 'Personalisation of Cardiac Models for the Clinic'. He discussed how expensive cardiac resynchronisation therapy (CRT) was not beneficial for everyone and how information processing should be integrated into the clinical workflow. Through the data fusion of electrical and anatomical information, better informed clinical decisions could be made as to who should benefit most from the treatment and how.

Cardiac arrests

Next, Christina Orphanidou (Oxford University) discussed another project, on 'Patient Monitoring in the Hospital of the Future', focusing on cardiac arrests. Apparently there are around 23,000 avoidable in-hospital cardiac arrests in the UK every year, and the challenge of the project aims to identify those patients who are deteriorating and act early enough to counter a potential cardiac arrest. Through the data fusion of patients' vital signs and a probability-based anomaly detector, an alert is provided with an alarm rate superior to existing methods. In a clinical trial of the method across 1,660 patients there was only one false alarm in 4.4 days.

Matthew Bultelle and Mike Guo (Imperial College) then spoke about their project 'The T-continuum: A Framework for Healthcare-Data Management', where the issues of the huge storage and processing problems of omics-data and a web-based EPHR (electronic patient health record) were raised. The Discovery-Net Grid backbone was used for illustrating integration of different datasets along with an analyser, data masking and performance analytics.

After lunch, David Glasspool (Edinburgh University) talked about the Edinburgh-Imperial-Oxford project on 'Safe and Sound'. After discussing the evidence that healthcare is unsafe, the deployment of clinical decision support systems was covered. Architectures of such systems were contrasted from the centralised ideal to the distributed and fragmented reality. Using LCC (lightweight co-ordination calculus) as an interaction logic between agents, demonstrators are to be developed exploring centralised orchestration of services to a choreography of distributed services.

The next talk was by our host, Rajesh Ransing, on the Swansea University project 'Challenges in Predicting Patient Pathways'. The data explosion and 'Google World' highlights the need for professional consultation with doctors. The talk emphasised the requirement for the interdisciplinary approach, and integration of consultation, patient data, analysis and software tools capable of meaning-based symbolic processing. The resulting earlier detection and accurate decision-making leading to reducing overall costs for the National Health Service (NHS).

Glyn Elwyn (Cardiff University) followed with 'Patient-centred Early Detection Models: Setting a Research Agenda'. The vision was to identify an early window of opportunity to detect, assess and treat early. This motivates the desire to seek predictive changes in performance or behaviour in clinical symptoms and signs. This promotes a 'Lifeworld Ecology' to fit into the patient lifestyle, thus extending the discussion to detection and social systems which support active healthcare management before a person becomes a patient, a theme picked up on the second day.

Error trapping

Harold Thimbleby's (Swansea University) talk on 'Human Error: Active Error, Latent Error, IT and the Grand Challenge' provided a fascinating insight into the lack of error-trapping and consequences in computer systems' designs, especially inside medical devices. The simple mantra for a grand vision of 'Design for Errors' may go some way towards reducing the many preventable hospital deaths by human error.

The next talk was by John Hand of EPSRC in his guise as Head of the Research Councils UK (RCUK) Digital Economy programme: a cross-council activity which also saw representatives of the Medical Research Council (MRC) in the audience. John is in charge of the area that has funded these current Grand Challenge scoping studies, and he highlighted the requirement for real need with impact, to create new communities of researchers and users. John pointed out the prior funding, including pump-priming, workshops, Doctoral Training Centres (six funded to a tune of £34M), and three research hubs at a cost of £12M each. He raised issues of complexity, early adoption of technology, how to engage partners widely, and where Information-Driven Healthcare fits into the rest of the council portfolio. The message seemed to be a desire to focus around the hubs that have been established and Doctoral Training Centres.

One Wales strategy

Martin Murphy, the Clinical Director of Informing Healthcare Cymru (IHC), closed off the first day by emphasising some of the key issues on 'Challenges in Information-Driven Healthcare: the role of

s for healthcare

Informing Healthcare'. He was promoting a strategic approach to investing in the area by supporting new ways of working, including making time to think! An issue many of us would recognise, embrace and support! Discussing the 'One Wales Strategy', the IHC is working with Swansea to address some of the grand issues, such as demographic aspects including ageing, increases in chronic disease, dementia, dependency and the social structures of modern families.

The informatics challenges were discussed, including the demand for patient-driven on-line booking and prescriptions – pushing the long overdue agenda for common person-friendly user interfaces; a safe and coherent information environment for clinicians – again requiring common interfaces; and the requirement to improve the predictive capability and support for early targeted intervention and predictive risk models.

Many of us who attended the excellent evening social will have some difficulty in living it down. Suffice it to say, that the professional salsa dancers in the NCAF membership should have been in the 'Bollywood' dancing lesson instead, and rumours of my own appearance in a 'Bollywood' production have been significantly exaggerated! However a special mention should rightly be made of the Chairman's expertise and his handling ability in not dropping the very brave and scantily clad salsa teacher. I never knew rottweilers could move like that!

Patient monitoring

The opening talk of the second day was given by David Clifton (University of Oxford) on 'Intelligent Patient Monitoring: A Machine Learning Approach'. David is working jointly alongside clinicians in the Emergency Department of the Oxford Cancer Hospital on a 'real system' to replace the paper-based aggregate scoring approach of acutely ill patients, with a more continuous and more reliable sensor data fusion approach to monitor patient departures from 'normality'.

In the second talk of the day, John Williams (Swansea University) gave a clinician's perspective on information-driven healthcare. From his perspective, the current Grand Challenge is to improve data capture communication and presentation of information for patient and clinician, and so improve this interaction between patient, doctor and computer. He pointed out the problems of incomplete handover information on a patient in a typical hospital process, and the problems of multiple ambiguous data and systems. John himself is using geneCIS (**www.genecis.co.uk**) for his patients to address some of his concerns.

The last formal presentation of the event was by Perumal Nithiarasu, from Swansea's Civil and Computational Engineering Centre who introduced us to work as part of an EPSRC network grant on patient-specific modelling. As part of this work he told us about the advantages of cross-boundary activity of fluid dynamics and computational fluid dynamics (CFD) from aircraft design into blood flow models for better design of equipment, to help optimise patient-specific devices.

What then followed was a departure from the NCAF norm: a set of break-out sessions splitting the attendees into three separate discussion groups on the major themes identified during the workshop.

One group focused on 'Information Technology – Solution or Problem?' This group discussed the current poor design of IT systems, mismatch of requirements and expectations, fragmentation issues, and also analysed how new IT structures could or should be designed that work in the NHS environment; in particular how to produce patient-centric solutions, not business or process oriented.

Another group discussed the four themes of (i) patient/doctor-centric solutions, (ii) error trapping, (iii) data overload and data complexity problems, and (iv) patient pre-screening (by computer/via internet – moving some of the load away from the doctor and placing some responsibility with the patient for active healthcare management). In particular, noting that what patients require and what IT the NHS needs to function are not the same thing.

The final group considered the issues of dealing with the whole person rather than just as a patient – i.e. active whole-life healthcare management rather than prognostic medicine. This discussion included: smart analysis using ambient healthcare technologies; remote and incidental sensing; and how much predictability can there be in genome versus lifestyle. Also discussed were the issues of cost-benefit analysis for wider society implications and whether appropriate metrics (quality of life per byte) could ever be constructed to allow society to make some of the big decisions needed if some of the truly fundamental issues facing the NHS are to be tackled.

Patient-driven healthcare

Our final combined discussion session had full audience participation – talking over some current real concerns. It was noted that whilst many research and political grand questions were being raised over providing geographically remote or even global patient record access, the big problems halting true progress were really at the local level. There is a fundamental conflict between the top-down mechanisms currently in place contrasting with the idea that patients (and potential patients) are a diverse collection of individuals. Patient-driven healthcare is the key, rather than management of service or organisation-wide processes. Coincidentally, the reader might like to access 'Research Fortnight', Issue 321 (April 2009), for two views on patient rights with regards to patient healthcare data and records in a research context: one from Fleur Fisher on 'Patients deserve the last word', and an opposing perspective from Mark Walport on '... But individual consent is not always feasible'. There is much we have yet to learn, absorb and incorporate into our healthcare research agendas. The NCAF event was a wonderful vehicle to highlight how far we have yet to travel.

Many thanks must go to the local organisation from Swansea University and, in particular, to Rajesh Ransing and his team for laying on a most enjoyable, extremely busy and thought-provoking event.

David Lowe
Aston University

PUZZLE CORNER

Number 42

At the annual convention of the 'Mathematically Inclined Recombinant Entrepreneurs', Mr and Mrs Axelrod and Mr and Mrs Beelzebub were on the same table as Lisa and 'Slippery Sam'. The couples had never met before and neither Lisa nor Sam knew anything about their mystery dinner guests. After exhausting all the usual topics like the state of the economy and whether Armageddon is just around the corner, the conversation drifted around to their families.

It transpired that both couples had two children. Sensing an opportunity to make a fast buck, 'Slippery Sam' interjected to stop too much information exchanging hands before he could make his pitch. He asked Mrs Axelrod if she had a boy and, if so, on what day of the week he was born. She replied, "Yes, Fangio was born on a Tuesday." Sam then asked Mrs Beelzebub if she could make a similar statement about her family. She replied, "Yes, I also have a son, Damian, who was also born on a Tuesday. Spooky!"

After denying vigorous accusations from Mr Beelzebub that Sam's real name was Derren Brown, he quickly ran through some mental gymnastics before he said to Lisa, "Seems to me that the possibility of all four children being boys is about 20%. So, will you give me odds of 4-1 on that wager?"

Should Lisa take on the bet, and if she did what would be her expected return?

The answer will be given at the next NCAF meeting (19–20 January, Aston University).

Fenella the Rottweiler

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Natural Computing Applications Forum

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Obituary
Chris Hawthorne

We regret to announce the death of Chris Hawthorne of Forum Public Relations who passed away on Easter Sunday (12 April). He had been diagnosed with early onset Alzheimer's in 2005 at the age of 59. Chris had edited and produced *Networks* since its inception in January 1994.

Common Uncertainty Theories

I was recently invited to give a presentation on uncertainty analysis in engineering dynamics at an NCAF meeting in Sheffield. As a result of bad time-management (a recurring problem), only about half of the material was presented. For those of you who gave a sigh of relief at the end of the presentation, I'm afraid there is no escape: here is much of the remainder.

An appropriate model of, or means of characterising, uncertainty is a vital element in the design and modelling procedure for high-value engineering structures and systems – this is the problem of *quantification*. As discussed later, there are numerous theoretical frameworks which allow a specification of uncertainty, and thus further problems arise in *translating* between specifications. Equally important in the design process is a prescription for deciding how a measure of uncertainty on the inputs or specification of a problem will affect the outputs or results – this is the problem of *propagation*.

For reasons of space, only the first problem will be discussed for now as it is arguably the most fundamental one. It is a useful exercise to examine some of the more common uncertainty theories: we shall see how the different theories allow different characterisations of uncertainty, ignorance and vagueness.

Classical Probability Theory: This is well-known. In fact, if the variations in a parameter are random, there is no better specification of the uncertainty than a probability distribution. However, in practice this will not often be available; engineering analysis is routinely based on small samples and one might only be able to estimate the low order moments of a distribution – mean and variance – with any confidence. Arbitrarily imposing a known distribution shape e.g. Gaussian, on the basis of this information is perilous. In particular, the use of such central statistics may result in a distribution radically different in the tails from the true distribution. In risk analysis, where one is concerned with extreme events, the results of such a strategy will probably be meaningless. Another problem is that a specification of a problem will necessarily include a region of ignorance and classical probability theory cannot accommodate this. In particular, a statement of the probability of an event automatically fixes the probability that it will not occur: ignorance is not modelled.

Evidence Theory: This can be regarded as an extension of the theory of probability (although this interpretation is contested). The main theory of this sort is the Dempster-Shafer theory, (the same Dempster (A.P.) who gave us the EM algorithm). Essentially, the single probability is replaced here with two quantities. The *belief* associated with an event is the sum of the evidence in favour of the event. The *plausibility* is the complement of the evidence against the occurrence of the event. By the fact that these quantities can be different, DS theory accommodates the idea of ignorance. DS theory thus replaces the single probability with an interval [*belief*, *plausibility*].

Possibility Theory: Like DS theory, possibility theory makes use of two complementary uncertainty measures – possibility and necessity. Essentially, some proposition e is mapped into the interval $[0, 1]$ which may be divided into the three intervals, necessity $N(e)$, necessity of the contrary proposition $N(e')$ and ignorance $I(e)$. Possibility of the proposition will be given by $P(e) = N(e) + I(e) = 1-N(e')$. In some ways, possibility theory can be interpreted in terms of fuzzy sets.

Fuzzy Logic: This is one of the elder statesmen of contenders with probability theory, having originated with the word of L.A. Zadeh in 1965. This extends classical probability theory by relaxing one of its fundamental set-theoretic properties. In classical set theory, an element x is either a member of a set A, or a member of its complement A^c. In fuzzy set theory, x may be associated (with given weight) with a number of different sets. Fuzzy logic encodes uncertainty by associating linguistic descriptors with a variable x like *large* or *small*. x may be a member of both sets large and small, but it is associated to each by a membership function which mediates the likelihood of its membership. There are analogues of all the basic mathematical operations for such fuzzy variables (often based on interval arithmetic) and it is possible to construct fuzzy analogues of many 'crisp' theories. The most extensive use of fuzzy logic in Engineering so far is associated with control problems.

Interval Methods: Rather simply stated, this replaces 'crisp' variables with intervals. Uncertainty in a parameter is encoded in the statement that it lies somewhere between two given bounds with certainty. This information *could* be incorporated in a probabilistic analysis by giving a distribution (e.g. uniform) for the parameter over the interval, however interval analysis makes no use of such additional assumptions. There are again analogues of all the expected arithmetical operations which thus allow the propagation of interval quantities through various types of models. The problem with interval arithmetic is that it is conservative in nature and that the bounds on the calculations expand considerably in practical computations, particularly if they are recursive. An attempt to improve on this behaviour is under development in the form of affine arithmetic.

Convex Models: In a sense, these can be regarded as a generalisation of the interval concept of uncertainty (although they are more than this). With a given parameter p is associated a convex set which may be said to contain the parameter. For example, an ellipsoidal-bound convex model takes the form,

$$I(a, p) = \{p : (p - \bar{p})^T W (p - \bar{p}) < a\}$$

where a specifies the axes of the ellipsoid containing the data: this is a convex set. This approach to uncertainty was pioneered by Ben-Haim. It is possible to prove numerous theorems such as: if the input to a linear system is a convex model, then so is the output. This property does not hold for a nonlinear system, but by relaxing the constraints one obtains an information-gap model and recovers the property of invariance under a nonlinear operator. One recent application of info-gap theory has been the development of a robustness criterion for neural network models.

One of the interesting issues in the field of uncertainty analysis for engineering problems is that there is a school of thought that only probability theory is ever needed. For example, it has been argued that interval-based approaches will never be optimal as we can surely always unearth more information on a quantity than its bounds; e.g. we can elicit further information from experts. I am personally of the opinion that the other theories described here have something to offer over probability theory for real problems and would be very pleased to hear from any readers of *Networks* of evidence in support of this claim.

Keith Worden
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