ToScA

Tomography for Scientific Advancement

Programme 2016

NATURAL HISTORY MUSEUM

UNIVERSITY OF BATH
Established 1966

Welcome to...

www.nhm.ac.uk/tosca

ToScA

Tomography for Scientific Advancement

6th-7th Sept. 2016, University of Bath

In affiliation with the Royal Microscopical Society (RMS)

Royal Microscopical Society

and in partnership with CCPi Tomographic Imaging

The University of Bath

The Edge Arts Centre

Claverton Down Rd,

Bath,

North East Somerset

BA2 7AY

Welcome to the Tomography for Scientific Advancement symposium (ToScA) 2016!

A warm welcome to ToScA 2016. I am delighted to announce that the ToScA symposium is now in its fourth successful year and is continuing to go from strength to strength. By sharing ideas, networking across the industry and demonstrating innovative developments, the event provides an ideal arena for the international micro-CT community and associated businesses.

We are grateful to the University of Bath for their support especially as Bath is a UNESCO World Heritage Centre. Our evening reception and symposium dinner at the famous Assembly Rooms in Bath will provide an opportunity to review the Poster submissions as well as a chance to network with academics, industry leaders, scientists and researchers.

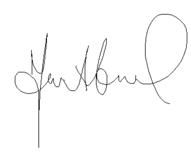
We are also grateful to all our sponsors and associates who have helped make the event possible. Also this year we are pleased to announce that selected research presented at the symposium will be published as an invited special issue in Biomedical Physics and Engineering Express (BPEX), from Institute of Physics publishing.

ToScA promises a community-led approach, where topics for discussion are chosen by the delegates and an opportunity to explore the direction of tomography is provided. This year we have 12 invited speakers, 15 contributed oral presentations and 20 poster with lightning talks.

This year, we have also initiated the Jim Elliott Best Paper Award in memory of Jim who passed away in December 2015. Jim was a dedicated researcher and wrote over 140 papers. His pioneering work in crystallography and X-ray microscopy drew attention from other disciplines. Jim was highly respected as a faithful mentor and as a diligent researcher.

On behalf of the entire organising committee, I hope you will find the symposium interesting and stimulating and I wish you a warm welcome to Bath.

We look forward to welcoming all.



Dr Farah Ahmed – ToScA Chair

It is my great pleasure to welcome all delegates, sponsors and speakers to The University of Bath, proud hosts of the 4th annual conference on Tomography for Scientific Advancement (ToScA). Bath was founded as a thermal spa by the Romans and is designated as a World Heritage Site by UNESCO, I hope you enjoy your time with us. It is fitting that ToScA comes to Bath in 2016 which coincides with the 50th anniversary of the University. Led by the Engineering Tomography Lab (ETL), The University of Bath is establishing itself as a global leader in all areas of tomographic imaging. We are excited to see the establishment of ToScA as a key event in the tomography calendar and I look forward to many stimulating talks and discussions throughout the next couple of days.

Dr Manuch Soleimani— ToScA Co-chair

Associates

CCPi Tomographic Imaging

Software Sustainability Institute

IOP Publishing

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FEI

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ORS Object Research Systems

North Star Imaging NSI An ITW Company

bluescientific

LaVision Focus on Imaging

Volume Graphics Solutions About Voxels

Pre-Conference Workshops

Workshops will be held on Monday 5th September 2016 at the University of Bath in **Building 4 East, level 2, room 39** and will cover Avizo, VGStudio Max and Drishti.

FEI Pore network modelling using Avizo (9:00-11:30am)

Participants will be offered the chance to try a new series of features for extending analyses performed on porous materials.

Avizo currently offers advanced quantification features for computing volumes on each porosity individually, including surfaces, shape characteristics, orientations, distance to the surface of the object, and distance to the nearest neighbour.

The software's new features allow the study of the porous network as a whole. This extension simplifies the representation of the pores and the pore throats in the network. It enables filtering of the pores based on various criteria, along with the computation of measures such as permeability or tortuosity. During the workshop, participants will use Avizo to perform a full analysis of porous material.

VGStudio MAX 3.0 (12:00-2:30pm)

This workshop will introduce CT data analysis and visualisation using VGStudio MAX. VG will present selected features of special interest for the scientific community for precise and fast analysis of voxel data:

- quantitative analysis options
- segmentation
- advanced visualization techniques

VGStudio MAX enables the effective extraction of information from data sets. During the workshop, you can use data provided by VG or your own tomography data, which may be acquired by laboratory X-ray CT, a synchrotron, with neutrons or another source. VG experts will be on-site to answer questions.

Drishti/Prayog (3:00-5:30pm)

Drishti is an exploration and presentation tool for volumetric datasets.

This workshop will cover recent developments in Drishti Paint - a manual segmentation tool. Drishti Paint offers techniques such as livewire, graphcut and fiber tracking for manual segmentation of data. 3D Viewer provides users with a 3D painting facility to aid and visualise segmentation. Participants are encouraged to bring their own datasets to try out the techniques.

ToScA 2016 Includes...

Poster and Image Competition

Posters representing the eight different sessions will be displayed and the winner of the competition will be awarded at the evening banquet, supported by CCPi.

The stunning images submitted for the competition will also be on show to view and the winner will be awarded at the evening banquet, supported by Nikon.

Both posters and images will be exhibited in the magnificent Assembly Rooms at 7pm on Tuesday 6th September along with a drinks reception.

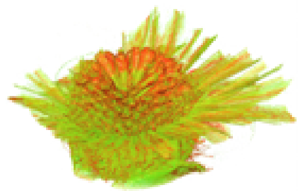
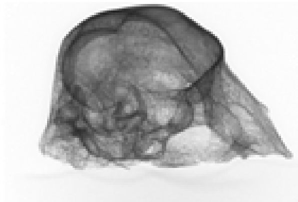
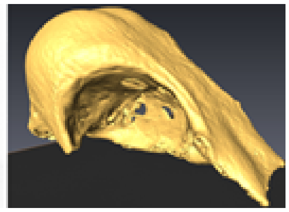
This will be followed by a banquet dinner at 8pm.

Awards

Travel awards will be supported by Zeiss & University of Bath and Lightning Talk awards will be supported by Institute of Physics and are to be presented at the banquet dinner on Tuesday 6th September.

Jim Elliot Best Paper Award

The winner of the Jim Elliot Best Paper award will be announced at ToScA 2017!

CCPi
Tomographic
Imaging

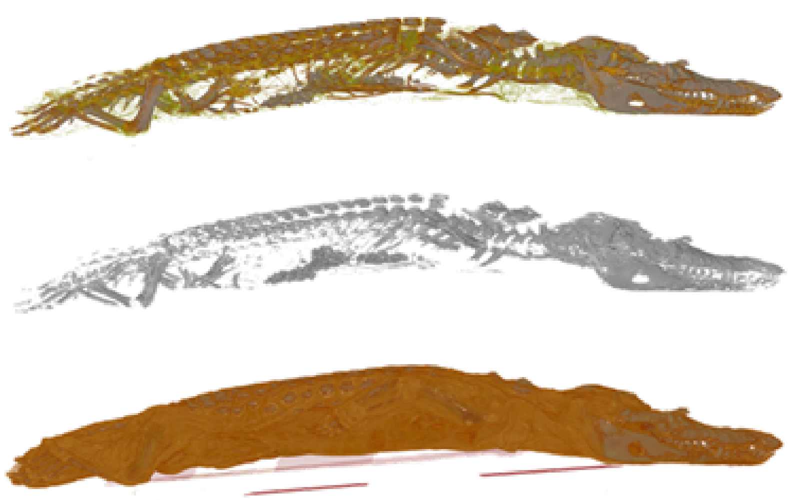
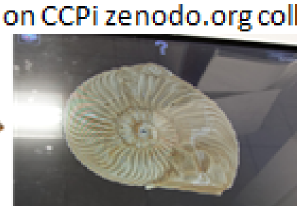
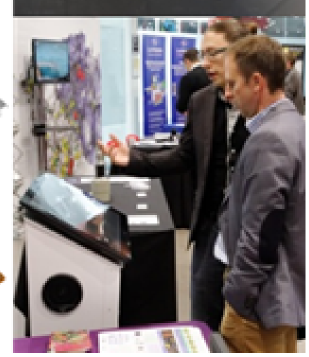
Collaborative Computational Project in Tomographic Imaging: www.ccpi.ac.uk

CCPi aims to provide the UK tomography community with a toolbox of algorithms that increases the quality and level of information that can be extracted by computer tomography. Chaired by Prof Philip Withers (University of Manchester) and co-ordinated by staff in the Scientific Computing Department of the Science and Technology Facilities Council it is led by a working group of experimental and theoretical academics with links to the Diamond Light Source, ISIS Neutron Spallation Source and Industry.

- We are creating and supporting; three frameworks from the national facilities to lab based.
- Extensive public engagement and interactivity via a Specialist Visualisation Sub Group.

The remit is to bring together the imaging community, maximise return on investment in software development and ensure longevity, sustainability and re-use of code. Currently there are special interest groups in image reconstruction, image quantification, image-based modelling and instrumentation. CCPi is funded by the Engineering and Physical Sciences Research Council.

- Software Developer Workshops
- Tomography software show-and-tells
- Explore the CCPi channel on YouTube
- Data archive on CCPi zenodo.org collection

Join over 300 Tomographic Imaging practitioners by emailing: ccpi@stfc.ac.uk

Credit for images: E. Yang, S. Nagella, A, Brown, R. Fowler, M. Turner, B. Searle (STFC), R. Atwood (DLS), T. Lowe, R Garwood, C. Price (Manchester)

EPSRC Engineering and Physical Sciences Research Council | MANCHESTER 1824 The University of Manchester | UNIVERSITY OF BATH | Science & Technology Facilities Council

Programme: Day 1

Tuesday 6th September

9:00-9:30	**Registration**
9:30-10:00	Opening Words: Farah Ahmed, Chair Manuchehr Soleimani, Co-Chair Prof. Bernie Morley Deputy Vice-Chancellor

Session 1: CT in Industry– Session Chair: Mike McCarthy

Time	Speaker	Title
10:00-10:20	Adam Truman, GSK	TBC
10:20-10:40	Andrew Ramsey, Nikon	Improved CT data quality
10:40-11:00	Cedric Dubois, Nestle	Can X-ray tomography help to develop novel food products? The examples of ice cream and chocolate
11:00-11:20	Nick Hansell, Dyson	How CT can assist innovation; and innovation develop CT

11:20-11:45	**Tea Break**

Session 2: Complimentary Technologies & Future Advances– Session Chair: Martin Turner

Time	Speaker	Title
11:45-12:15	Manjit Dosanjh, CERN	From Physics to Medical applications
12:15-12:30	Anna Zamir, UCL	Recent Advances in Edge Illumination X-ray Phase Contrast Computed Tomography
12:30-12:45	Genoveva Burca, STFC Rutherford Appleton Laboratory	Recent Developments of Combined imaging and diffraction techniques at ISIS
12:45-13:00	Bart Winiarski, FEI, University of Manchester	High Aspect ratio helical micro X-ray CT in materials science

13:00-14:00	**Lunch, Trade Exhibition & Group Photo**

Programme: Day 1

Tuesday 6th September

Session 3: Data– Session Chair: Ajay Limaye

Time	Speaker	Title
14:00-14:30	Mike McCarthy, NPL	Current developments of metrology standards for the dimensional verification of
14:30-15:00	Carola Schoenlieb, University of Cambridge	Seeing more in pictures– a mathematical perspective
15:00-15:15	Imanol Luengo, University of Nottingham	Hierarchical Regions for fast biomedical volume segmentation
15:15-15:30	Mark Basham, Diamond Light Source	Using Savu to analyse the temporal evolution of corrosion in Al and Mg samples
15:30-15:45	**Tea Break & Trade Exhibition**	

Session 4: Engaging the Public– Session Chair: Andrew Ramsey

Time	Speaker	Title
15:45-16:05	Jessie Maisano, University of Texas	DigiMorph.org: Past, Present & Future
16:05-16:25	Graham Davis, Queen Mary University, London	A Novel way to look at Voxel Data
16:25-16:40	Edward Stanley, Florida Museum of Natural History	Maximizing the scientific and educational utility of natural history collections through computed tomography
16:40-17:15	Lightning Talks	
17:15-18:00	**Panel Discussion**	

Programme: Day 2

Wednesday 7th September

Session 5: Materials Science– Session Chair: Manuchehr Soleimani

Time	Speaker	Title
9:00-9:30	Cornelia Vacar, FEI	Fiber Analysis in Avizo
9:30-9:45	Stephen Price, Diamond Light Source	Multimodal Chemical Imaging of Catalysts Underoperating Conditions
9:45-10:00	Marcus Hanwell, Kitware	Tomviz: Open Source, Scalable Platform for Reproducible Materials Tomography
10:00-10:15	Matthew Curd, University of Manchester	3D imaging of white etching cracks (WECs) in bearing steels
10:15-10:30	William Lionheart, University of Manchester	Rich and non-abelian tomoraphy: strain and magnetic fields
10:30-11:00	**Tea Break**	

Session 6: Bioengineering & Life Sciences– Session Chair: Alex Ball

Time	Speaker	Title
11:00-11:30	Dr. Leah Lavery, Zeiss	3-D X-Ray Microscopy in Life Sciences
11:30-11:45	Anton du Plessis,	Venomous snake fangs: microstructural analysis by 3D micro and nanotomography and FE Modelling
11:45-12:00	Zerina Johanson, Natural History Museum	Diversity of skin denticles in fossil and extant rays and the origins of vertebrate dentitions
12:00-12:15	Gavin Taylor, Lund University	Imaging the last impression of an ancient eye
12:15-13:15	**Lunch & Trade Exhibition**	

Programme: Day 2

Wednesday 7th September

Session 7: Earth & Space– Session Chair: Zerina Johanson

Time	Speaker	Title
13:15-13:45	Gerhard Prenner, Kew	Quantitative floral development using micro-CT imaging
13:45-14:00	Amin Garbout, Natural History Museum	Soil in CT
14:00-14:15	Kate Dobson, Durham University	Mobilising multi-phase magmas: Strain localization during flow of non-Newtonian suspensions
14:15-14:45	**Tea Break & Trade Exhibition**	

Session 8: Medical Applications– Session Chair: Graham Davis

Time	Speaker	Title
14:45-15:15	Mark Williams, Warwick University	Use of micro CT to characterise the anatomy of the femoral ACL footprint to validate reconstructive surgical techniques
15:15-15:30	VN Wijayathunga, University of Leeds	Use of tomographic imaging and 3D image processing to characterise the articulation geometry of the natural talocrural (ankle) joint.
15:30-15:45	Mark Greco, Charles Sturt University	Applying Tomography to Learning and Memory in Bees
15:45-16:00	Natalie Reznikov, Imperial College London	Golden lotus: Adaptation of trabecular bone of the human foot to altered function
16:00	**Final Remarks**	

Session Chairs

CT in Industry	Mike McCarthy NPL
Complementary Technologies & Future Advances	Martin Turner University of Manchester
Data	Ajay Limaye University of Canberra
Engaging the Public	Andrew Ramsey Nikon
Materials Science	Manuchehr Soleimani University of Bath
Bioengineering & Life Sciences	Alex Ball Natural History Museum
Earth & Space	Zerina Johanson Natural History Museum
Medical Applications	Graham Davis Queen Mary University, London

How to find us

The conference proceedings will take place at The Edge Arts Centre near the east car park, next to the Sports Training village.

Public transport: The easiest way to travel to the University is by public transport. You can travel to Bath by train and bus and the nearest train station is Bath Spa.

There are a number of frequent bus services available. The U1, U18, X18, U10, 20A and 20C services all start and terminate at the centre of campus, and travel through the city centre.

Driving: If you are driving and want to use a satnav to find your way to the University, the GPS coordinates are latitude 51.378344, longitude –2.325202.

Please note that the main entrance to the campus is accessed via Norwood Avenue (BA2 7BA, not Quarry Road. Pay & Display parking for drivers is available on campus. There is also parking for motorcycles and electric vehicles, with charging points.

Walking and cycling: There are a number of popular cycling and walking routes to the University, with facilities such as showers and cycle parking sheds available across campus.

There are many taxi companies operating in Bath. Taxi ranks are located in front of the train station, next to the Abbey and at the University itself.

DisabledGo provides access information for our campus and facilities. Including information on parking, wheelchair points and lifts.

UNIVERSITY OF BATH

www.bath.ac.uk

Key

CENTRAL ADMINISTRATION

- 4W Vice-Chancellor's Office
- 4W University Secretary's Office
- WH Admissions
- WH Registry
- Manvers Street Finance Office & Purchasing Services
- 6W International Relations Office
- WH Student Records & Examinations
- 4W The Roper Student Services Centre
- WH Human Resources
- 4W Graduate Centre
- WH Marketing & Communications
- East Building Development & Alumni Relations
- WH Research & Innovation Services (RIS)
- WH Widening Participation

FACULTY ADMINISTRATION

- WH Faculty of Science
- 2E Faculty of Engineering & Design
- 1W 1WN Faculty of Humanities & Social Sciences
- 8W School of Management

AMENITIES & SERVICES

- 1 Library - Security and Enquiries
- 2 Chaplaincy Centre
- 3 Chancellors' Building
- 4 Founders Sports Hall
- 5 Athletics throws & jumps/Modern Pentathlon
- 6 Sports Training Village/Sports Café
- 7 50m Olympic Swimming Pool
- 8 The Edge/ICIA/School of Management
- 9 Arts Lecture Theatre
- 10 University Hall
- 11 Bale Haus
- 12 Medical Centre & Dental Centre
- 13 Student Centre, Union Shop
- 14 Estates Office
- 15 Central Stores, Goods Received, Landscape
- 16 West Accommodation Centre
- 17 Westwood Nursery
- 18 Fresh Grocery Store
- 19 Applied Biomechanics Suite
- 8W IDPS (Imaging, Design and Print Services)
- WH Post Office, Banks & Shops
- NH Careers Service

DEPARTMENTS

- 4E 6E Architecture & Civil Engineering
- 4S Biology & Biochemistry
- 9W Chemical Engineering
- 1S 3S Chemistry
- 1W Computer Science
- 3E Economics
- 1WN Education
- 2E 4E Electronic & Electrical Engineering
- 6WS 1W Eastwood Health
- The EDGE 8W East Building School of Management
- 6W 4W Mathematical Sciences
- 4E 6E Mechanical Engineering
- 1S 3S Natural Sciences
- 5W 7W Pharmacy & Pharmacology
- 3W Physics
- 1WN Politics, Languages and International Studies
- 10W Psychology
- 3E Social & Policy Sciences

FOOD & DRINK

- 2W Claverton Rooms, Parade Bar, Fountain Canteen
- 4W 4 West Café
- WH Wessex Restaurant
- the Quads lime tree refectory
- The Edge CAFE
- 6 Sports Café
- NH Plug Bar & the TUB
- NH Starbucks, Fresh Express, Pitstop Costa Coffee, Proper Pasty

ACCOMMODATION

- Brendon Court
- Eastwood
- The Lodge
- Marlborough Court
- Norwood House
- Osborne House
- Polden Court
- The Quads
- Solsbury Court
- Westwood
- Woodland Court
- The Woodlands

- City Bus Service
- Fire Assembly Points
- P Parking: Pay & Display and Permit Holders
- P Parking: Permit Holders only

Places to stay

Hilton, Bath City

http://www3.hilton.com/en/hotels/united-kingdom/hilton-bath-city-BATHNHN/index.html

Holiday Inn Express, Bath

http://www.expressbath.co.uk/

Francis Hotel, Bath

http://francishotel.com/

Premier Inn, Bath City Centre

http://www.premierinn.com/gb/en/hotels/england/somerset/bath/bath-city-centre.html

Travel Lodge, Bath Central

https://www.travelodge.co.uk/hotels/75/Bath-Central-hotel

The Queensberry Hotel, Bath

http://thequeensberry.co.uk/

University of Bath Accommodation

http://www.bath.ac.uk/groups/guest-accommodation/

ToScA Committee 2016

Chair: Dr. Farah Ahmed

Co-chair: Dr. Manuch Soleimani

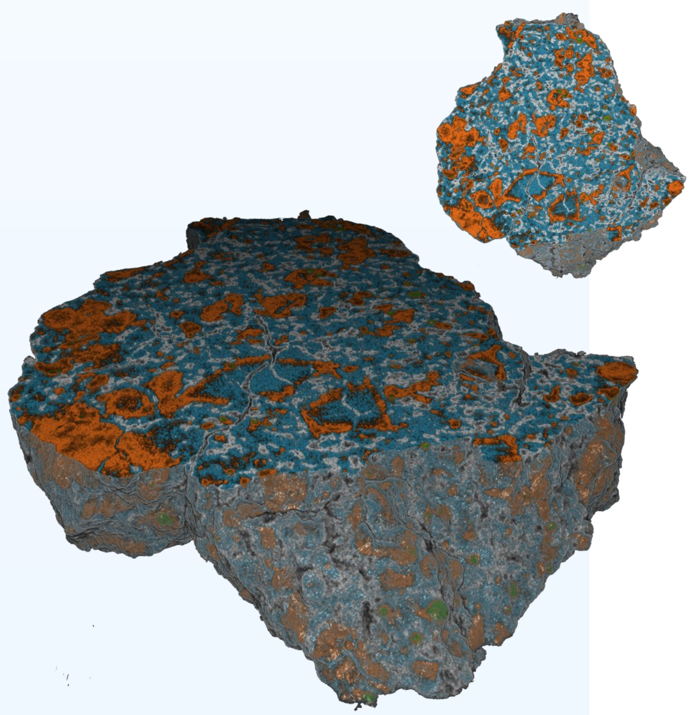
Local Committee (University of Manchester):

Manuchehr Soleiman
Ann Linfield
Ander Biguri
Manasavee Lohvithee

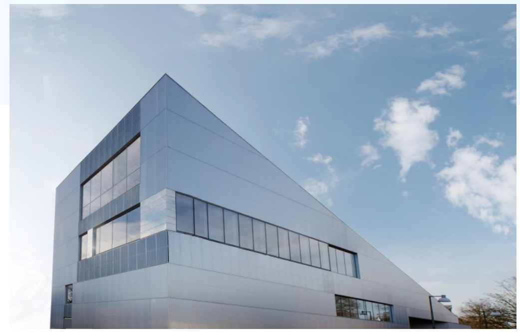
Planning Committee (Natural History Museum, London):

Louise Turner

Alia Rehman



University of Bath



History

The University of Bath was granted university status in 1966 by Royal Charter, however our roots can be traced back to the Bristol Trade School - a technical school established in 1856.

In 1885 the school was renamed the Merchant Venturers' Technical College and in 1929 the Bath School of Pharmacy became part of the college.

By 1960 the college had become the Bristol College of Science and Technology and, following the Robbins Report of 1963, which recommended immediate expansion of universities, began to look at gaining university status.

With the college rapidly expanding and no suitable site available in Bristol, a chance conversation between the college principal and the Director of Education in Bath led to an agreement to provide the college with a new home in Claverton Down, Bath.

The first building on campus was completed in 1965 (becoming the building now known as 4 South), just a year before the Royal Charter was granted.

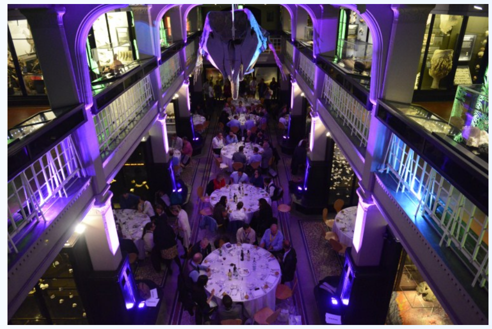
University Logo

Our logo features a Gorgon's head which is based on a Roman sculpture found in Bath during the 1790s and was used originally on our coat of arms.

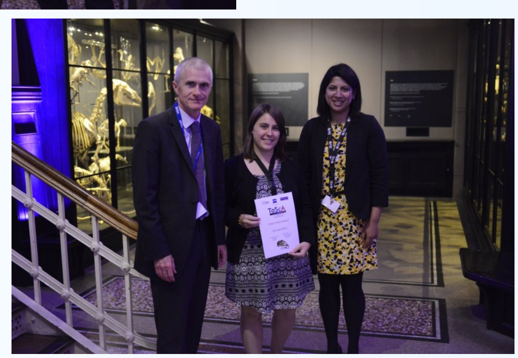
It was discovered during the digging of foundations for the Roman Baths.

It was part of a great ornamental pediment that sat over the entrance to the temple where the statue of the goddess Sulis Minerva was housed.

ToScA 2015 Highlights



ToScA 2015 Competition Winners



What's on in Bath?

Tour of Britain (8th September)

Bath & North East Somerset Council will welcome the Tour of Britain, British Cycling's premier road cycling event, this September for the first ever stage finish of the race to take place in the historic city of Bath.

The Jane Austen Festival (9th-18th September)

The Festival kicks off annually with the spectacular Grand Regency Costumed Promenade with over 500 participants.

A Handful of Dust at the Holburne Museum (ends 18th September)

As part of our '100 Years Here' celebrations, the Holburne will be exhibiting some of its rarely-shown but exquisitely beautiful eighteenth-century British portraits in pastel

For more info visit:

http://visitbath.co.uk/whats-on

Celebrating 175 years of the Journal of Microscopy

RMS

Recent Articles in Tomography

Accurate stochastic reconstruction of heterogeneous microstructures by limited x-ray tomographic projections

Iodine potassium iodide improves the contrast-to-noise ratio of micro-computed tomography images of the human middle ear

Non-rigid alignment in electron tomography in materials science

Comparison of three-dimensional analysis and stereological techniques for quantifying lithium-ion battery electrode microstructures - OPEN ACCESS

Structural stress responses and degradation of dictyosomes in algae analysed by TEM and FIB-SEM tomography

Experimental investigation of craze morphology of isotactic polypropylene using computed tomography

Welcome to the Journal of Microscopy

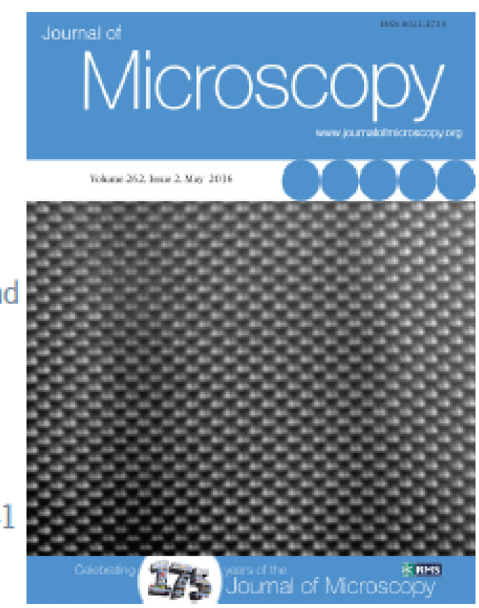
The Journal of Microscopy is celebrating its 175th year of publishing leading research in a broad range of fields with a focus on the microscope, the novel techniques used and the groundbreaking results they can identify.

The Journal of Microscopy, published by Wiley on behalf of the RMS, is proud to be ranked in the **top 3 international microscopy journals** with a current Impact Factor of **2.136.**

As a **hybrid journal,** the Journal of Microscopy accepts both open access and non open access papers.

The Journal of Microscopy publishes quality original research articles, review articles, Hot Topic papers, and letters to the Editor, covering all aspects of microscopy and analysis. This includes cutting-edge technology and innovative applications in physics, chemistry, material and biological sciences. The Journal is for scientists and technologists who develop, advance or apply any form of microscopy, cytometry, spatially resolved spectroscopy, compositional mapping & image analysis. The Journal of Microscopy is particularly interested in papers on original applications & developments in microscopy.

You can view the online library of journal articles all the way back to 1841 on Wiley Online.



www.journalofmicroscopy.org

RMS WILEY

Abstracts Day 1: 6th September

CT in Industry

Cédric Dubose - Can X-ray tomography help to develop novel food products? The examples of ice cream and chocolate

X-ray tomography is currently used in the food industry as the only non-invasive imaging technique which allows us to quantify the 3D internal structure of solid and semi-solid food matrices. This technique is usually used in absorption mode to link the sensory properties of food to the processing parameters during production. For instance the pore size distribution and wall thickness of breakfast cereals are the main drivers of liking for a given recipe.

The recent development of X-ray tomography in large facilities (PSI, DESY) with higher resolution and faster scanning time using alternative imaging mode (e.g. phase-contrast imaging) allowed us not only to characterize multi-component food matrices at the micrometer scale but also to study the dynamics of food during shelf-life.

Notes:

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Tomography for Scientific Advancement
6^{th}-7^{th} Sept. 2016, University of Bath

Complementary Technologies & Future Advances

Manjit Dosanjh– From Physics to Medical Applications

CERN is the world's largest particle physics research laboratory. Its contribution to particle physics and to related technologies has been outstanding since its establishment in 1954.

The challenging demand for particle physics has pushed the detector performance to very high limits both in terms of spatial and time resolution and the cross-fertilization between particle physics detectors and imaging tools is bringing real benefits to society.

Many important diagnostic and therapeutic techniques are based on either basic physics principles, or the technologies developed to conduct physics research. They include PET scanners, MRI imaging, and radiation therapy for cancer. Even the collaborative model of particle physics is proving its worth in catalysing multidisciplinary research.

Physics has been and continues to be instrumental in the development of technologies in the biomedical domain especially the use of ionizing radiation for medical imaging and therapy ever since the discovery of X-rays by Roentgen in 1895.

A. Zamir, CK Hagen, M Endrizzi, PC Diemoz, FA Vittoria, PRT Munro, A Olivo- Recent Advances in Edge Illumination X-ray Phase Contrast Computed Tomography

X-ray phase contrast imaging (XPCi) has been the focus of extensive research in recent years due to the advantages it offers in comparison to conventional, absorption-based X-ray imaging. Along with X-ray absorption, XPCi systems are also sensitive to the refraction of X-rays, often resulting in higher image contrast. The sensitivity to X-ray refraction can be achieved using different approaches, one of them being the Edge Illumination (EI) method which is suited for use with both coherent and incoherent radiation (e.g. synchrotron radiation and laboratory X-ray sources, respectively).

The EI method has been adapted for use as a computed tomography (CT) modality as well, finding use in a wide range of applications and in different environments. Recent work has been carried out with the aim of optimising the performance of EI CT while keeping it versatile. In particular, two approaches have been considered: low-dose, fast CT, and long, high-resolution CT scans.

To reduce scan times, a continuous sampling scheme was implemented and then also combined with the "reverse-projection" method. Additionally, scan times can be further reduced using a new phase retrieval algorithm, where only one frame is required at each projection image instead of two.

Moreover, spatial resolution higher than that dictated by the pixel size can be achieved in EI by a process termed "dithering". This, however, requires longer acquisition times that typically lead to significant artefacts in the reconstructed slices due to the limited system stability. To solve this problem, a new phase retrieval method accounting for both system misalignment and instabilities over time was developed and demonstrated to improve both quantitative accuracy and image quality.

This talk will outline the fundamentals of the method, briefly discuss the above recent advances, and present examples of application in a variety of areas across the life and physical sciences.

G. Burca, W. Kockelmanna, J. Kellehera, S. Kabraa, J.A. Jamesb, T. Minnitia, F. Montesino-Pouzolsa- Recent developments of combined imaging and diffraction

The need to enhance the material analysis capabilities at ISIS and complement the existing neutron analysis facilities led to the construction of a new cutting-edge neutron imaging and diffraction facility for materials science (IMAT) at the second target station at ISIS.

The instrument will allow for spatially and energy-resolved neutron imaging and diffraction. In addition to conventional 'white-beam' neutron radiography and tomography applications, IMAT will offer energy-selective imaging for mapping microstructural properties down to a spatial resolution of 50 microns. IMAT will also offer residual strain analysis, phase analysis and texture analysis by neutron diffraction.

While neutron tomography provides three-dimensional maps of attenuation coefficients, thereby giving the opportunity of visualising the inside of an object in a non-destructive manner, neutron diffraction methods provide information on the distance between crystallographic lattice planes at specific points which is used for neutron strain scanning.

The complementarity between neutron tomography and neutron diffraction will be exploited through the technique *tomography driven diffraction* (TDD) based on the SScanSS software for different samples drawn from the engineering and heritage sciences.

Employing this method, on IMAT, it will be possible to perform tomography, mark the measurement points and proceed to the diffraction measurements as one continuous process.

A wide range of scientific and technological areas and topics will be covered on IMAT such as engineering, archaeology and biology. Moreover complementary studies with X-ray imaging from other facilities will be investigated. One particular direction will be development of correlative neutron and X-ray computed tomography to study water distribution and structural deformation at the micro-scale in plant and soil systems.

B. Winiarski, G. Pyka, T. L. Burnett, Y. Wang and P.J. Withers- High aspect ratio helical micro X-ray CT in materials science

X-ray computed tomography (XCT) used in material science recently adopted helical scanning trajectory that is particularly attractive for the imaging of slender specimens. This opened access to a range of complex samples, man-made materials and natural structures not practical for circular scanning, e.g. fibre-reinforced composite samples, additively manufactured components in material science, long cylindrical cores of rock formation in geology, etc. Standard laboratory systems use circular cone-beam scanning thus high aspect ratio samples can be scanned in sections and stitched together afterwards. This workflow is time-consuming and has the potential to introduce a number of errors. More importantly is the fact that reconstruction of the cone-beam scanners through the use of filtered back projection algorithms, such as the FDK algorithm, means that Tuy's condition is only true for the central horizontal plane and the reconstructed data becomes unusable for any quantification close to the extremes of the volume. Helical trajectory scanning is free from this constrain and the reconstructed data is faithful to the original. Cone-beam artefacts are not introduced during the reconstruction as the effects of the cone-beam geometry are avoided as the sample is scanned with a helical trajectory. Tuy's condition is satisfied for the entire sample volume allowing rigorous quantification of the whole reconstructed dataset.

We will show the latest helical micro XCT results from our FEI Heliscan system with application to materials science. This will include data from fibre-reinforced composite materials, geological core samples, abrasive materials, safety matchstick and mus musculus femur. We will show the relative advantages and disadvantages of helical scanning and demonstrate the types of materials and structures that can be scanned. Finally, we will show the implementation of a helical trajectory iterative reconstruction algorithm which shows some benefits for reducing beam hardening artefacts.

Data

Michael McCarthy PhD- Current developments of metrology standards for the dimensional verification of XCT systems.

Dr Michael McCarthy's presentation will review the traceability of the metre with particular reference to engineering, cultural heritage and scientific three-dimensional co-ordinate measurement applications.
An overview of the current ISO-10360 Series which addresses Geometrical Product Specifications (GPS) – Acceptance and reverification tests for coordinate measuring machines will be presented. This will cover both tactile and optical / non-contact probing systems.

Details on the current status in the development of a new XCT 'standards document' which is currently at a draft status and also intended to be added to the already well established range of ISO-10360 documented standards will be described. In particular a number of currently proposed 'material-artefacts' designed to demonstrate the dimensional performance of an XCT system will be presented. Some of the benefits and perhaps weaknesses of each 'material-artefact' will be reviewed.

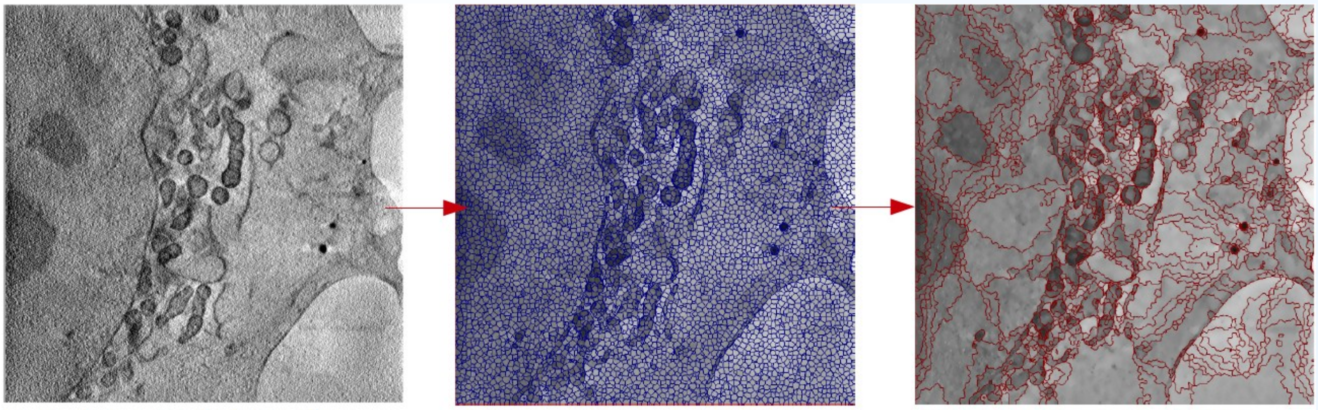
Imanol Luengo- Hierarchical Regions for fast biomedical volume segmentation

The amount of data generated by current bio-imaging techniques is currently overtaking our ability to efficiently analyse it. In order to analyse a biomedical volume, expert knowledge is required to visually explore the volume and manually tag different areas/sections of it for measurement. This manual segmentation labour is tedious, error prone and time consuming.

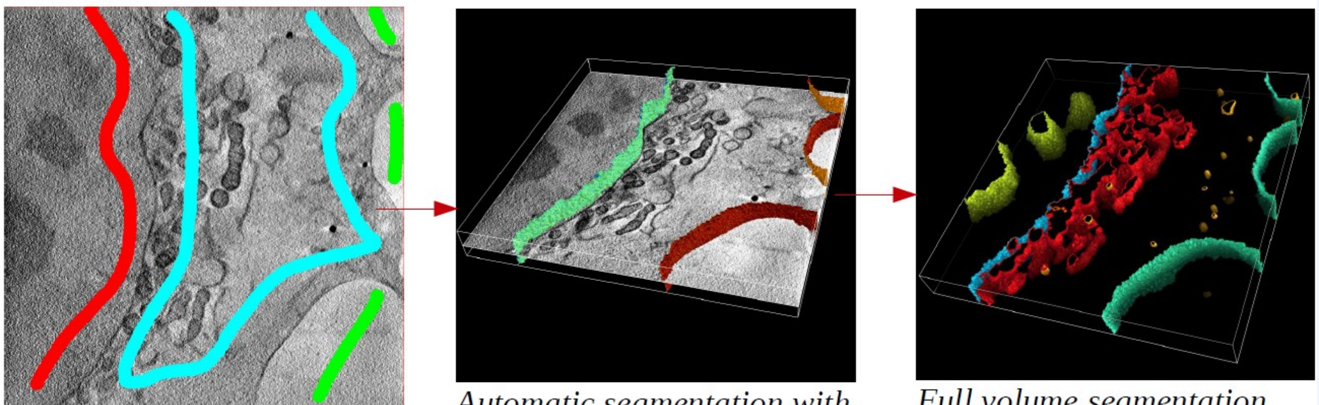
Over the past decade, many computer vision approaches have been introduced to the medical imaging community with the aim of automatizing the segmentation process of large medical volumes. Biological volumes, however, are still very challenging as they contain hundreds of objects of interest (e.g. organelles inside a cell) with a wide variety of textures and shapes.

Here we propose a super-region based approach towards semi-automatic large volume segmentation. The biomedical volume is first segmented into large and homogeneous regions (called *super-voxels*) in a completely unsupervised fashion. These *super-voxels* group neighbouring and similar voxels together, partitioning the volume in larger regions while preserving strong volume boundaries (between organelles and cell areas, or organs in medical images). These regions are further clustered together, creating larger partitions of the volume at every hierarchical iteration.

Once the hierarchical partition is created, a human-user could explore the volume and fully segment it by annotating those regions. Annotating becomes then much easier and less time consuming, as the human expert doesn't need to worry about accurate boundary annotations. Quick scribbles annotate previously created whole regions, which already adhere to volume boundaries. Additionally, standard computer vision techniques can be directly applied to the hierarchical regions to obtain coarse segmentations automatically, while being several orders of magnitude faster.



Sample central slice of a Cryo-SXT Volume — *Initial region partition* — *Further region partition*



User Annotations — *Automatic segmentation with regions (regions are in 3D!)* — *Full volume segmentation with further annotations*

Mark Basham- Using Savu to analyse the temporal evolution of corrosion in Al and Mg samples.

Aluminium and magnesium alloys are prone to localised corrosion brought about by atmospheric salt particulates and understanding these processes provides insights and data for predictive models used to predict corrosion damage to aircraft. We have conducted experiments where the effects of cycling the relative humidity between wet and dry conditions are investigated to assess conditions where corrosion will be accelerated in the same corrosion sites, leading to accumulation of corrosion damage, or re-started in new sites leading to minor roughening of the surface. These experiments used a continuous rotation acquisition method which allows for tomograms to be collected with fine time slicing but low resolution. The data was collected with an interleaved pattern so that during post processing multiple tomograms could be combined for higher resolution if needed and both high and low resolution could be intermixed to get the required temporal and spatial information.

During the experiment at Diamond Light Sources I13 Imaging Beamline, over 6TB of raw data and around 1600 separate tomography scans collected. This poses significant issues for data processing, especially with complex and novel data collection strategies as implemented with these experiments. Savu is a freely available, open source, and most critically, extensible Python package for the reconstruction of tomographic data. The work presented here details how Savu was extended to allow for this specialist data collection, and the methods introduced to make the most of the available temporal and special resolutions. It then details how this could be applied automatically to the significant quantities of data involved to accelerate the scientific process.

Engaging the Public

Dr. Jessie Maisano- DigiMorph.org: Past, Present, Future

The Digital Library of Morphology, or DigiMorph.org, was created to make web-sized visualizations derived from high-resolution X-ray computed tomography (HRXCT) scans freely available to the public. DigiMorph went live in 2002 and now serves HRXCT imagery for more than 1000 specimens, from the oldest-known dinosaur to a fire ant decapitating fly. It represents a collaborative effort between the University of Texas High-Resolution X-ray CT Facility and nearly 300 researchers from the world's premiere natural history museums and universities. DigiMorph serves supplemental imagery for more than 200 peer-reviewed scientific publications, and is a significant resource for the repurposing of HRXCT data sets. Despite these successes, it has proven difficult to secure additional funding to take DigiMorph to the next obvious level of functionality: serving as an official repository of HRXCT data, analogous to GenBank. Should DigiMorph strive to help researchers meet the U.S. National Science Foundation's Data Management Plan requirements for making HRXCT data available and for their long-term conservation, or continue to focus on serving HRXCT-derivative visualizations to the general public?

Graham Davis - A Novel way to look at Voxel Data

With the advent of phone cameras, the concept of pixels is almost universally understood; but until around five years ago the 3D voxel was unheard of except almost exclusively amongst a handful of imaging researchers. Today, however, the second most popular video game of all time, Minecraft, is voxel based. Even if gamers themselves have not heard the term, they cannot fail to be familiar with the concept. Since public engagement for science is about taking science to where people are, a project was devised to take voxel data from micro-CT scans and import it into Minecraft, allowing gamers to interact with data representing real specimens. In this feasibility study, a human tooth was scanned and imported into the Minecraft world. Dental tools were created in the game environment, allowing gamers to drill and fill the tooth. Different parts of the tooth have different hardness and texture to represent enamel, dentine, pulp, decayed enamel, decayed dentine and calculus. Early feedback from dentists has been very positive and there are plans to use this approach for teaching about dentistry, oral hygiene and to reduce anxiety in children awaiting dental treatment. There is now a special educational version of Minecraft available for use in the classroom. Whilst this may be useful for formal education, it is hoped that, with further development, the novelty value of interacting with this type of data will encourage children to download these 'mod's and thus be educated whilst "wasting time" on video games.

Edward Stanley and D. Blackburn- Maximizing the scientific and educational utility of natural history collections through computed tomography

Scientific collections of amphibians and reptiles serve the global research community as storehouses of biodiversity information. While genomic and distribution data are readily available for download and reuse through online collections databases and portals such as GenBank and the Global Biodiversity Information Facility (GBIF), most studies of morphological variation continue to rely heavily on examining and handling the preserved specimens in collections. Recent advances and increased access to Computed Tomography (CT) open up new avenues for increasingly integrative morphological research. To facilitate scientific research and education related to amphibian and reptile diversity, we are systematically generating a digital library of phenotypic diversity using microCT scanning. These data are used in research focused on systematics, evolution, paleontology, and comparative and functional anatomy. Using microCT scanning, we generate three-dimensional (3D) volumes of external and internal anatomy for morphological descriptions as well as quantitative analyses of surfaces and volumes such as with geometric morphometrics. Because the method is not destructive, we can easily integrate type specimens and rare species into our studies. Like other forms of digital data, images and 3D volumes can be shared easily (see http://bit.ly/UFHerpMorph) and repurposed for other forms of future research and education (including 3D printing). We are able to capture and quantify traits that otherwise would be difficult in traditional preparations, such as osteoderm distributions or cranial endocasts. Through contrast-enhanced microCT scanning using, for example, Lugol's iodine we can also visualize soft tissues such as muscles, nerves, and arteries. We expect that emerging digital 3D resources for amphibian and reptile morphology will renew interest in phenotypic diversity and evolution and make our scientific collections accessible to more people than ever before.

Abstracts Day 2: 7th September

Material Sciences

Stephen Price, A.M. Beale, A Parsons, J.F.W. Mosselmans—Multimodal Chemical Imaging Of Catalysts Under Operating Conditions

The imaging of catalysts and other functional materials under reaction conditions has advanced significantly in recent years. The combination of the computed tomography (CT) approach with methods such as X-ray diffraction (XRD), X-ray fluorescence (XRF), and X-ray absorption near edge spectroscopy (XANES)[3,4] now enables local chemical and physical state information to be extracted from within the interiors of intact materials which are, by accident or design, commonly inhomogeneous. The spatially resolved signals obtained can reveal information on the microstructure of the sample that would otherwise be lost in bulk measurement. Such local signals are simpler to interpret since they are highly likely to contain fewer phases. Studying intact materials rather than idealised powders allows for behaviour under industrially relevant conditions to be observed. Furthermore the background signal from in situ apparatus / cell can be readily separated.

We show how such methods have been applied to understanding the behaviour of catalytic systems under operating conditions (packed bed 500 µm micro-reactor containing Co/SiO_2 Fischer Tropsch catalysts at 200 °C and 4 bar pressure). Crucially we demonstrate that the obtained chemical and physical information can be correlated to catalytic activity and selectivity. At these small length scales, sample size and density allow for transmission of comparatively low energy signals allowing a combination of XRF-CT and XANES-CT in conjunction with XRD-CT, enabling simultaneous multi-technique imaging.

Marcus D. Hanwell, S. Waldon, Y. Jiang, C. Quammen, E. Padgett, DA. Muller, R. Hovden—

Tomviz: Open Source, Scalable Platform for Reproducible Materials Tomography

Materials tomography using transmission electron microscopy (TEM) involves a number of steps to go from projection images taken on the microscope to an aligned, reconstructed 3D volume.

The Tomviz project builds upon a number of open source frameworks to deliver a powerful desktop application for research, leveraging the Python environment along with a number of scientific Python modules to deliver a comprehensive solution for materials tomography at nanoscale to atomic resolution. The development of the application will be discussed, along with the Pythonbased data processing pipeline, and the XML format used to enable complex, reproducible data processing and visualization pipelines. The application is based on Qt, VTK, ParaView, and ITK with a bundled Python distribution making use of NumPy, SciPy, and Python wrapped ITK/ParaView to offer a powerful visualization and data analysis application.

The development, packaging, and deployment of a robust, crossplatform application for materials tomography will be discussed. The current state of reproducible analysis and data processing pipelines demonstrated, and future directions will be discussed. The use of Python will be demonstrated within this context. Reproducibility is a key problem in science, and complex data collection, alignment, reconstruction, and processing pipeline are particularly important. This project is funded by the DOE SBIR program, and is an active collaboration between developers at Kitware and scientists at Cornell University.

Matthew Curd - 3D imaging of white etching cracks (WECs) in bearing steels

White Etching Cracks (WECs) are commonly found in the stressed subsurface regions of bearings and can lead to the early onset of failure through a process known as White Structure Flaking (WSF). They are distinct from conventional cracks in that they are surrounded by an altered microstructure consisting of nano-grained ferrite, which appears white when etched with Nital. This microstructure is named (WEA) and it is debated whether it is a precursor to the crack or just symptom of the damage.

By means of X-Ray computed tomography (CT) the morphologies of subsurface WEC networks were examined in a sample of AISI 52100 grade martensitic bearing steel. This allowed for visualisation of the subsurface WECs, in addition to nearby features such as voids and inclusions. In addition to the non-destructive X-Ray CT, WECs were investigated using two destructive serial-sectioning approaches. The first approach used a plasma focussed ion beam (P-FIB) to mill regions of interest for electron microscope analysis. Unlike in the reconstruction of the X-Ray CT data, the P-FIB was capable of resolving the WEA from the surrounding material. The second approach utilised an Argon based broad ion beam (BIB) to excise larger regions beneath the contact surface. 0Imaging of the sample was then conducted using both secondary electron (SE) and electron back-scattered diffraction (EBSD) modes of an electron microscope. When combined, the images from these two modes allowed for 3D visualisation of both the crack and the WEA morphologies.

It is hoped that in the future these techniques can be used together within a correlative framework to study WECs in more detail and hopefully elucidate details regarding the formation mechanisms of these cracks.

William Lionheart, N. Desai, S. Schmidt, P. Withers- Rich and non-abelian tomography: strain and magnetic fields

Increasingly we need to image quantities with more degrees of freedom than a simple scalar, vector fields such as the magnetic field in a magnetic domain, or a tensor field such strain. To do this tomographically we need richer data then one scalar per line. In many cases the relevant transport equation involves matrix multiplication and this gives rise to non-abelian tomography problems. In other cases what is measured is a projection of the vector or tensor field in the transverse or longitudinal directions.

As new tomographic measurement modalities arise we need to understand what data is needed for a stable reconstruction and how to do that reconstruction numerically.

We focus on two examples. Neutron spin tomography promises to be a method to image magnetic fields and so to help in the design of advanced magnetic fields. This is non-abelian but can be analysed to some extent with known theory. We present a slice-by-slice non-linear reconstruction algorithm for which only one rotation of the sample is needed. X-ray diffraction tomography for strain reduces to the Transverse Ray Transform for a symmetric tensor field. We give an algorithm and reconstruction of simulated data for data from three rotation axes.

We show that a plausible published method for Bragg edge neutron tomography of strain does not work.

Bioengineering & Life Sciences

Anton du Plessis, S. Gerhard le Roux, C. Broekhoven- Venomous snake fangs: microstructural analysis by 3D micro and nano tomography and finite element modelling

A series of venomous snake fangs were analyzed by high resolution microCT, with the aim to investigate the internal microstructure, specifically the morphology of the venom canal. This venom canal differs considerably in shape between species. Two major shapes are found: open and closed canals, while the ejection area also has different angles relative to the fang, depending on the species and its nature of ejecting venom (eg. Spitting vs biting). The shape and detail of each canal is described in detail for the range of venomous snakes investigated. This is a unique set of data as it involves very high resolution micro and nanoCT with some fangs having a total length of only 1-2 mm. By making use of finite element modeling of the obtained CT data, the fangs of different species can be compared in terms of their strength. Results obtained from such modelling will be discussed.

Zerina Johanson, C. Underwood, Brett Clark, GJ Fraser, M. Welten, J. Kriwet5, C. Pfaff5, M. Smith, M- Diversity of skin denticles in fossil and extant rays and the origins of vertebrate dentitions

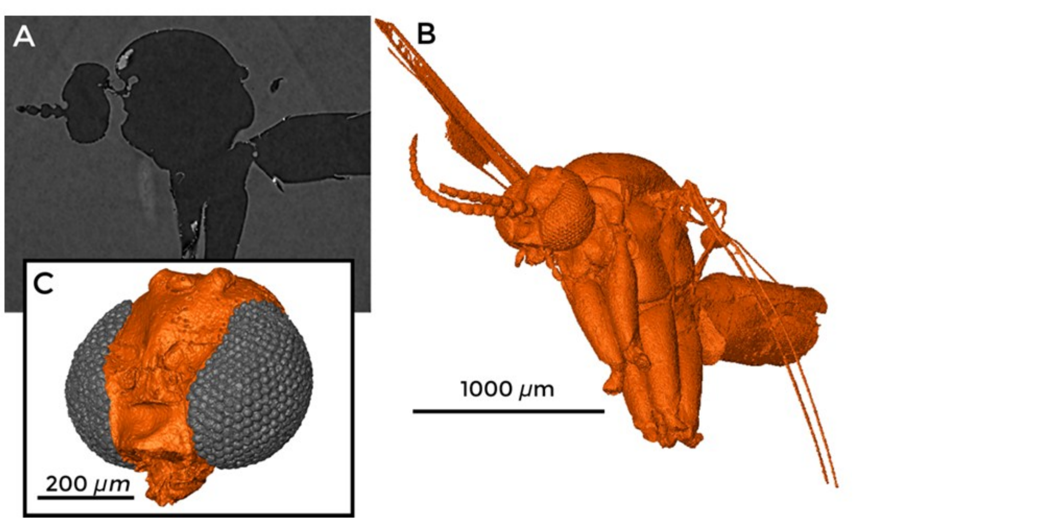
Sharks and rays have been studied extensively to address the origin and evolution of teeth. They possess an external dermal skeleton comprising scales (skin denticles) similar in composition to teeth (e.g., dentine), but arranged in patterns distinct from teeth organized into functional dentitions along the jaws. Enlarged and tooth-like denticles extend along the cartilaginous rostrum in sharks and rays, including sawsharks, sawfish and the fossil Sclerorhynchoidea, and are also present on the chondrocranium and various parts of the postcranial skeleton. Using Xray microtomography, we recorded the development of these denticles for closer comparison to teeth; current hypotheses propose that teeth evolved from external dermal skin denticles, predicting that these structures should share developmental and patterning mechanisms, including addition and replacement.

In sawsharks and fossil Sclerorhynchoidea, the rostrum tip represents a growth centre where new denticles are added. Although an extended rostrum is absent in living rays, patterned denticles occur at the anterior margin chondrocranium, suggesting the presence of a similar growth/organizing centre. Denticles along the rostrum are added and replaced, but only when loss occurs; this developmental mechanism also applies to the enlarged denticles on the ray chondrocranium, neural arches and pectoral girdle. Rostrum denticles in fossil sclerorhyncoids, especially *Schizorhiza,* also rotate into position, in an unusual two-step manner. Although these denticles show some regulation, they differ from oral teeth in chondrichthyans and also osteichthyans, where functional and replacing teeth are part of a successional series linked by tooth-producing tissues (e.g., dental lamina). In rays, denticle replacement is more comparable to that of regular external skin denticles/scales, providing no evidence to support current hypotheses of tooth evolution.

Gavin Taylor, S. Hall, J. Gren, E. Baird- Imaging the last impression of an ancient eye

The lenses of an animal's eyes are the optical windows through which it perceives the visual world. As both the optical and neural elements of an eye are energetically costly to develop and maintain, many animals have evolved specialized eyes that filter the incoming light to efficiently extract the visual information they require. Quantification of the three dimensional structure of an eye's optical elements can be used to calculate its visual performance which, like a camera, is defined by resolution and sensitivity. While the eyes of vertebrates are composed of delicate soft-tissue structures, the exterior of many invertebrate eyes are lenses formed from rigid cuticle. Hence, the cuticular lenses of insects, such as those in entomological collections, can preserve a lasting indication of their visual capabilities.

We imaged the eyes of a particularly old insect, a cranefly preserved in Eocene Baltic amber, using x-ray tomography at the Lund University 4DImagingLab. The insect's internal structure appeared to have disappeared, yet fitting a surface around its imprint clearly defines the former extent of its cuticle. The surface included fine anatomical structures, and allowed us to individually segment the cuticular lenses indicating the exterior of the fly's eyes. The optical axes of the lenses show the optical resolution of the eye, whilst their sizes provide an indication of sensitivity. Future studies using this method will compare related extant and (preserved) extinct species from a similar geographical region, to identify how their visual capabilities evolved in response to known variations in habitat and climate.



A virtual slice through the embedded insect revealed a hollow structure (A). However, a surface can be created over the imprint (B), from which the individual facets of the insect's compound eye can be identified (C).

Earth and Space

Gerhard Prenner, M. Conejero, F. Ahmed, C. Prychid- Quantitative floral development using micro-CT imaging

The study of floral development (i.e. the development of a flower from its first primordial stage to maturity) has a long tradition, starting in 1857 with a comprehensive account by J.B. Payer who documented light microscopy results with hundreds of minute line drawings. Scanning electron microscopy has allowed a more detailed analysis of early ontogenetic stages and invigorated ontogenetic studies. Defined comparative characters are used for detailed descriptions of flower morphologies, for systematic placement of species, genera and families, for the analysis of organ homologies and for questions regarding floral ecology. We use members of the legume or bean family (Leguminosae) as our study group. With almost 20,000 species it is the third largest flowering plant family. Legume crops are highly important for human nutrition and due to their nitrogen-fixing ability they are an important source for biological nitrogen in agricultural and natural ecosystems. Using micro-CT imaging techniques we aim to further broaden the output of ontogenetic studies by adding accurate volumetric measurements of developing floral organs and by describing the spatiotemporal dynamics of floral ontogeny. With micro-CT imaging, growth patterns and ontogenetic characters are traceable, measurable and comparable more accurately over time and space.

Kate Dobson J., Di Genova, D. Wadsworth, F.B. , Vassuer, J. , Marone, F., Dingwell D.B.- Mobilising multi-phase magmas: Strain localization during flow of non-Newtonian suspensions

Many complex fluids and multi-phase suspensions exhibit non-Newtonian rheology, but the micro-scale mechanisms that control these behaviors are poorly understood. This is because the interactions between solid, liquid, and gas phases have not been directly observed. We present an *in situ* high speed (1-2s per 3D image) x-ray tomographic study of two- and three- phase flow during concentric cylinder rheometric experiments. Using the novel XRheo beam line compatible rheometer we present a workflow that allows collection of "traditional rheology" stress-strain information while simultaneously tracking the motion of every particle, and quantifying the movement and deformation of every bubble within the sample volume.

We present data collected using the XRheo experimental rig at the TOMCAT (Swiss Light Source) beam line, and show how the rig can be utilized on any tomographic imaging system. Experiments have already yielded data under varying strain rates and in different rheological regimes. We show how this data can be used to constrain strain localisaiton and rheological compartmentalization in the fluid, and correlate this with the bulk properties of the system recorded *in situ,* in the traditional manner.

Medical Applications

VN. Wijayathunga, CL Brockett- Use of tomographic imaging and 3D image processing to characterise the articulation geometry of the natural talocrural (ankle) joint.

The articulation geometry is one of the key aspects that influence the mechanics of the natural ankle joint. Methods based on 2-dimensional depiction of the trochlear profile as a circular arc are found in literature to describe talotibial articulation. However, description of the geometric parameters of the articulating surfaces in 3D would significantly help the development of simulation models of the joint as well as preclinical testing of novel interventions for the ankle joint. Therefore the objective of this study was to identify key geometric parameters of the trochlear surface in 3D, related to the talotibial articulation.

Two cadaveric feet (age > 76) sectioned from the distal tibia were scanned using a high resolution computed-tomography (CT) and the image data were processed to produce 3D-surface renderings of the talus. The surface points lying on the lateral and the medial margins as well as the mid-sagittal line of the trochlear surface were recorded using 3D coordinates, as separate sets. A computational algorithm was developed to obtain the best-fit sphere for the each of the point sets using a least-square error method. The alignment of the spheres, their centres, and the sphere radii were evaluated in 3D as geometric parameters for characterising the articulating surface.

Best-fit sphere dimensions were determined as follows: lateral margin (x = 58.0 mm, y = 59.3 mm, z = 51.7 mm, radius = 21.5 mm); mid-sagittal (x = 68.6 mm, y = 57.3 mm, z = 49.1 mm, radius = 22.8 mm); medial margin (x = 78.1 mm, y = 55.2 mm, z = 49.4 mm, radius = 22.8 mm). The centres of the spheres were on a straight line on the transverse plane with the medial end of this line positioned more towards anterior. The sphere representing the lateral margin was smaller compared to the other two and was located marginally at a higher level axially.

Geometric parameters for the talotibial articulation could be derived using surface (sphere) fitting. These fitted surfaces are compatible with pronation/supination, and inversion/eversion motion, and hence provide a method for evaluation of these movements.

Mark Greco- Applying Tomography to Learning and Memory in Bees

The experiment was conducted as a “proof of principle” study to identify potentials for MicroCT scanning of live bee brains to be used as a non-invasive method for studying learning and memory.

A bench-top MicroCT scanner and a synchrotron Beamline were used to scan live bees. To enhance tissue differentiation, bolus injections of radiographic contrast were delivered directly into the haemolymph (Fig 1). Brain volume and plasticity data (Fig 2) were measured using BeeView software.

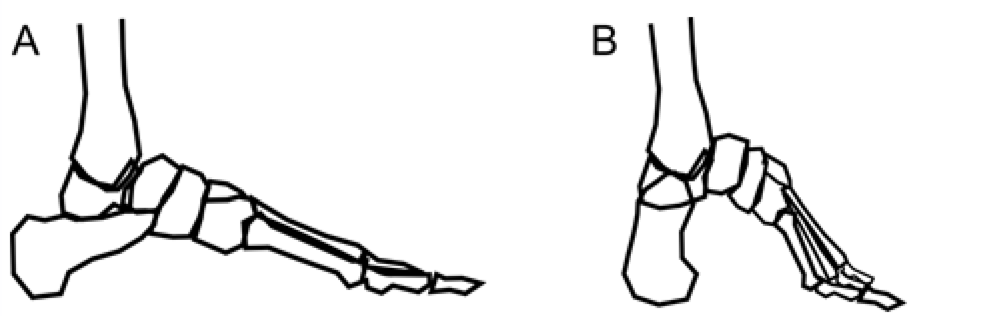
Gross brain morphology was visualised in 2D and 3D projections. Scanning of live bees enabled minimally-invasive imaging of physiological processes (for the first time) such as passage of contrast from gut to haemolymph (Fig 3) as well as preliminary brain perfusion and plasticity studies (Fig 4). Brain morphology results were correlated with learning responses in live bees.

Understanding the relationships between experience and brain structure is key to understanding the relationships between learning and memory. Simple environmental manipulations can both accelerate and delay brain growth in bees, and since brain volume and density are sensitive to behaviour throughout life, the honeybee has great potential as a model for exploring the interactions between learning, memory and brain structure.

The use of CT imaging for the non-invasive study of insects (termed Diagnostic Radioentomology-DR) is increasing (Greco et al. 2005; Greco et al 2008; Eyer et al 2015). Results from this experiment demonstrate limitations of live bee scanning however they also show the great potential for in-vivo, non-invasive DR imaging of the live honeybee for future research and teaching of brain morphology, physiology and function.

Natalie Reznikov- Golden lotus: Adaptation of trabecular bone of the human foot to altered function

The human foot is an amazing shock-absorbing system at the anatomical level (by virtue of the foot arches) and at the tissue level: the trabecular fabric of short bones has topological organization adapted for stress redistribution. In the bound foot (as per a historical cultural practice in China) the arch is folded and the heel bone acts as the lower leg extension. Hence, the shock-absorbing function is abolished at the anatomical level. This study compares the topological parameters of the trabecular fabric of the heel bone in normal and bound foot using a high-resolution micro-CT and calculation of the mean Inter-Trabecular Angle. The results elucidate the adaptational capacity of trabecular bone.



Schematic of the bones arrangement in (A) normal human foot and (B) bound foot.

Posters

CT in Industry

Code	Author	Title
001	Willliam Lionheart	Exact and iterative helical scan reconstruction on the Nikon XTEK Bay

Complementary Technologies & Future Advances

002	Valeriy Titarenko	Multi-source high speed scans of large objects with Rapiscan RTT 110

Data

003	Mario Sandoval	6DoF Input Device Integration for XCT Volume Visualisation
004	Valeriy Titarenko	Parallelising algorithms for x-ray tomography problems

Engaging the Public

005	Paul Wilson	A Sense of Touch: Getting to Grips with Museum Artefacts

Material Sciences

006	Parmesh Gajjar	Beyond a black box: "Hacking" a Nikon Metrology X-Ray CT Machine
007	Asa Barber	3D engineering at the Future Technology Centre

Bioengineering & Life Sciences

008	Sebastian Blunk	Enhancing Seed Germination for a Sweeter Tomorrow
009	Marie D Schmidt	What does a bee see? Using microCT to image the visual world of bees
010	Brett Clark	Quantitative analysis of chondrichthyans using X-ray tomograph
011	Dan Sykes	Learning from nature: Time-lapse 3D imaging of the mechanical behaviour of arthropod cuticle
012	D Bacheva	Novel hierarchical architectures: An inspiration from Nature
013	Mason Dean	Biological strategies for fatigue and wear avoidance: Lessons from stingray skeletons and teeth
014	Marcus Griffiths	X-ray Computed Tomography for non-invasive visualisation of root system architecture and root growth in soil
015	N Roberts	The ontogeny of human vertebral bone microstructure
016	James O'Sullivan	Visualising the parasitic nematode Trichuris muris using X-ray micro-computed tomography
017	Rebecca Summerfield	Using Micro-CT to unravel past bleaching events of Chagossian corals
018	Mark Thompson	Roots responses to compacted soils
019	Stephanie Robinson	3D Characterisation of Human Pulmonary Lymphatics and Microfluidic Modeling using Correlative Immunohistochemistry and High

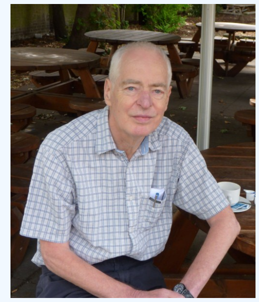
Earth and Space

020	Natasha Almeida	A Three-Dimensional Survey of Metal Grain Size Distributions in Ordinary Chondrites: Effects of Metamorphism

Medical Applications

021	Manasavee Lohvithee	Limited data cone beam CT using edge preserving total variation algorithms

Jim Elliot (20 September 1937– 30 December 2015)



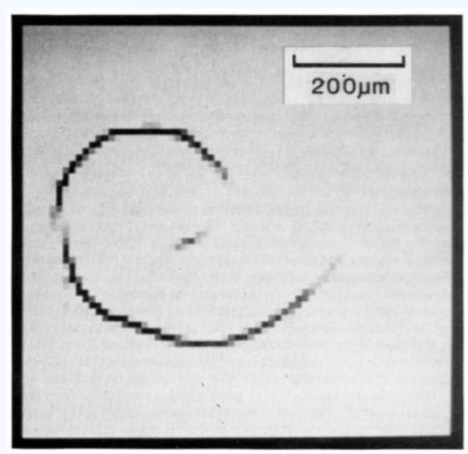
Professor James Cornelis Elliott:

James Elliott completed a PhD at the London Hospital Medical College in 1964, supervised by Professor Ron Fearnhead. He was subsequently appointed Lecturer in Biophysics, rising to Professor in 1993.

His thesis work covered the crystallographic structure of dental enamel and related apatites. He continued this work on the chemistry of apatites in dental enamel, which led to the publication of what is considered the seminal work on the subject, his 1994 book titled Structure and Chemistry of the Apatites and Other Related Calcium Orthophosphates.

This would be a significant contribution, were it Jim's only legacy.

He applied this chemical rigour to the understanding of the mineral chemistry of dental enamel and how this affected the progression of developing dental caries. He continued that association with dental research, and with what is now the Dental School at Queen Mary University of London, for the most of his career. He contributed significantly to the institute's research output, its teaching, and to its overall success in many different capacities.



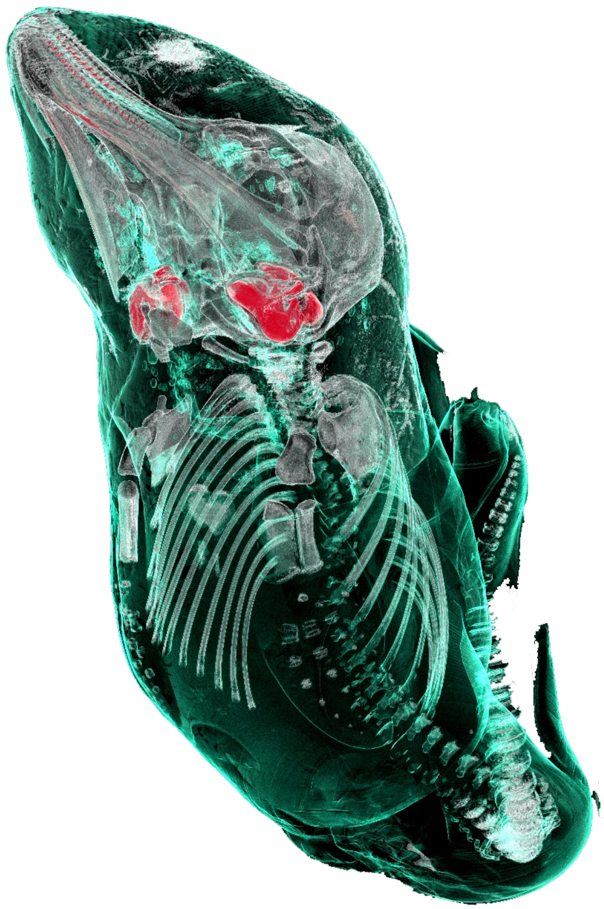
His study of mineral distributions in biological hard tissues led him to develop novel X-ray microscopic instrumentation - initially scanning X-ray microradiography, and subsequently a 3D X-ray microscopic method. In 1982, with David Dover of King's College London, he published the first ever X-ray microscopic tomographic image, of a water snail (Biomphalaria glabrata¸ right).

Over subsequent years, this methodology has developed into the well-known technique of micro-CT, which is now a standard tool in many laboratories around the world. There is no doubt that Jim Elliott's work in pioneering the micro-CT methodology has led to the development of the state-of-the-art 3D X-ray microscopic imaging systems that are available today. His development of micro-CT is another of his significant contributions to the worldwide scientific community over a wide range of scientific, engineering and medical disciplines.

Jim was a dedicated researcher and wrote over 140 papers. However, his pioneering work in crystallography and X-ray microscopy drew attention from other disciplines. Jim enthusiastically fostered collaborations between academic disciplines, recognising the power of interdisciplinary research within the university, nationally and internationally. Among his many colleagues, he was highly respected as a faithful mentor and as a diligent researcher.

We would like to extend our thanks to The Natural History Museum, The University of Bath, The Royal Microscopical Society, our sponsors, our speakers, the ToScA planning committee, Bath local committee and volunteers, and all the delegates.

-Team ToScA



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