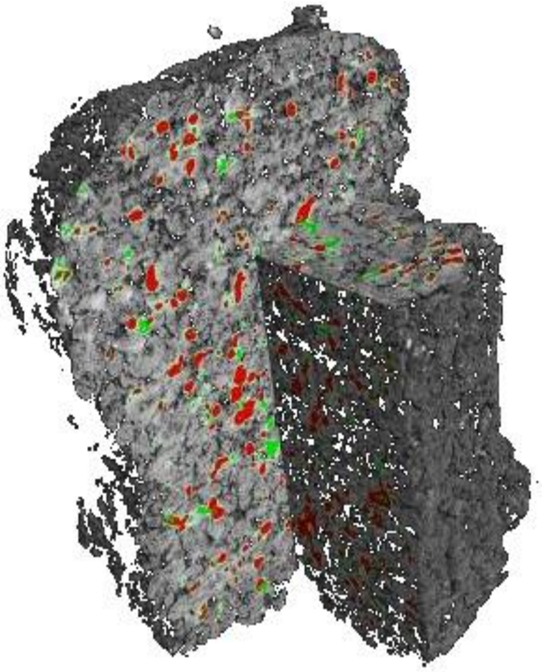
4th IMAGING WITH RADIATION CONFERENCE – IMGRAD 2021



ABSTRACT BOOK

South African Biennial Conference

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The Computer Tomographic Scanner: How Solving a Mathematical Algorithm Won a Nobel Prize in Medicine

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In November 1895 Wilhelm Rontgen performed an experiment in which invisible cathode rays, generated by electrostatic discharges from within an evacuated glass tube, and caused a cardboard screen to fluoresce. He called them X-rays, using the mathematical description for something unknown. Rontgen's discovery revolutionised medical diagnosis. Within a few weeks of the appearance of an X-ray image of his wife's hand, the technology was being used by clinicians all over the world. In 1901 he was awarded the Nobel Prize in Physics for his discovery of X-rays. If we then fast forward 50 years to Groote Schuur Hospital, and ten years before before Christiaan Barnard performed the world's first heart transplant, a far more momentous project in medical science took place in Cape Town. It is the story of the computer tomographic (CT) scanner.

Allan MacLeod Cormack was born in Johannesburg on 23 February 1924 and died in Boston on 7 May 1998. He was educated at Rondebosch Boys High School and then studied physics at the University of Cape Town and the Cavendish Laboratory at Cambridge University. In 1955 he was seconded to Groote Schuur Hospital as a nuclear physicist. As he later stated: "It was immediately obvious that the problem was a mathematical one. If a fine beam of γ rays of intensity I_o is incident on the body and the emerging intensity is I, then the measurable quantity

$$\text{g} = \ln(I_o/I) = \int_L f.ds$$

where f is the variable absorption coefficient along the line L. Hence, if f is a function in two dimensions, and g is known for all lines intersecting the body, the question is: Can f be determined if g is known?" Cormack was indeed able to solve this problem which he described in his seminal paper published in 1963 [1]. There was virtually no response to his paper, with the most interesting request for a reprint (there was one other) coming from the Swiss Centre for Avalanche Research who thought the method could be used to find skiers buried under the snow! Godfrey Hounsfield was educated in the Royal Air Force during World War II and then as an electrical engineer at Faraday House College in London. He subsequently worked for EMI research laboratories, began development of a brain scanner in the late 1960s, and his original prototype used gamma rays and required 28,000 measurements, taking 9 days. The pictures took 2.5 hours to be processed, and X-rays reduced collection time to 9 hours. The first clinical brain scanner was installed at Atkinson Morley's Hospital in London and the first images of a patient's brain were acquired on 1 October 1971. Allan MacLeod Cormack and Godfrey Newbold Hounsfield were joint winners of the Nobel Prize for Medicine in 1979 for their pioneering work in "the development of computer assisted tomography." The second half of my presentation will focus on the anatomy of writing a book about Allan Cormack [2]. In this personal odyssey, I will explore 12 topics, including the idea for the book, arranging my materials, securing a publisher, travelling to conduct background research, writing long hand or typing, importance of an editor, role of illustrations, selecting a title for the book, the cover design, enjoyment of the book launches, reviews of the book, and finally I will read two of my favourite passages.

[1] Cormack AM, 'Representation of a function by its line integrals, with some radiological applications', Journal of Applied Physics, 34(9): 2722-2727, 1963.

[2] Vaughan CL, Imagining the Elephant: A Biography of Allan MacLeod Cormack, ISBN 978-1-86094-988-3, Imperial College Press, London, 304 pages, 2008.

Analysis and Visualization of Scientific Tomography Data with VGSTUDIO MAX

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VGSTUDIO MAX is an established and powerful tool for accurately analyzing and visualizing volume data generated for industrial and scientific research. Our software works with data from a wide range of devices, such as industrial X-ray CT, medical X-ray CT, synchrotron tomography, neutron tomography, and MRI. VGSTUDIO MAX also allows users to simultaneously analyze data acquired from various sources. For example, an X-ray and a neutron scan of an object can be easily combined to obtain the most information from both methods. When analyzing scientific CT data, segmenting and visualizing different inner structures are often key tasks. Apart from providing a visual breakdown of the scanned object, segmentation can also reveal additional details about the scanned specimen. A preliminary advanced multi-material surface determination can significantly facilitate segmentation. It allows an object to be automatically separated into materials based on their different gray values, e.g., bone and soft tissue. Apart from identifying the inner components of an object, a functional analysis of morphological structures can also be of interest. Especially in the fast-emerging field of biomimetics, analyzing structure-function relationships is a key element. For example, a Digital Volume Correlation (DVC) analysis measures the displacement and strains in time series of volumetric images. This tool makes it possible to detect structural changes in two stages of an object, e.g., before and after mechanical loading. Additionally, DVC allows for a quick identification of specific materials by comparing scans acquired from different methods (e.g., neutron and X-ray computed tomography). Alternatively, direct structural mechanical simulation on voxel data is not only used to manufacture, for example, the ideal part for an airplane cabin holder but can also be used to simulate stress distribution in biological samples when a static force is applied. Since the simulation runs directly on the voxel data, inner features like voids can be factored into the simulation. By converting the voxel data into a tetrahedral volume mesh, the information on the inner structure can also be transferred to dedicated simulation software. Furthermore, a precise surface mesh of the scanned object can be exported as a model for 3D printing or for use in other software.

An Overview of the Stellenbosch CT facility - Latest Capabilities, Applications and Advances

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The Stellenbosch University computed tomography (CT) scanner facility is now almost 10 years old. The growth and development of this facility has been documented in previous works, with summaries of typical application types and research areas of interest [1, 2]. Despite the challenges, this facility has been financially secure and supported a wide diversity of research leading to hundreds of scientific publications, post-graduate student degrees and industrial applications in the local industry. In this paper, the latest capabilities and advances at the Stellenbosch CT facility are described, by focusing on research and industrial application highlights from the last two years. This includes particular efforts in advanced manufacturing, reverse engineering, failure analysis and product and process verifications for a variety of different partners. In research applications, areas of interest remain in advanced manufacturing engineering, geological and agricultural research, and archaeological and heritage object interest. In addition to this, some exceptional biomedical research has been completed in recent times that is worthy of mentioning. In this overview paper, the research interests and areas of particular expertise of each team member of the facility is also discussed, and areas of potential future collaboration are highlighted. Current efforts at big data management and data sharing are discussed, as well as new plans for this in the near future. One particular aspect that needs current attention is closer collaboration of the existing imaging facilities in South Africa, with a suggestion to acquire investment for the longer term sustainability of all these facilities in one flagship program, including opportunities for student bursaries and beam time awards, with funds for maintenance of existing equipment and potential for further growth and development of these.

3D Imaging at the Unisa - Mintek X-ray Microscope Facility

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Over the last decade, advances in X-ray computed tomography (XCT) have resulted in the extraction of important 3D data in the geo- and materials sciences. In South Africa, the establishment of three national centres for XCT has seen many researchers exposed to the technique for various applications. The Unisa-Mintek facility was recently established to add to 3D imaging capabilities in the country, using a Zeiss Versa 3D X-ray microscopy (XRM) system. The system affords high resolution scanning (to 0.7 um spatial resolution) of mm-to-cm-scale diameter samples, using a combination of geometric and optical magnification, and is therefore not limited by the focal spot size, as in conventional XCT. Furthermore, the configuration and detector system are optimised to allow enhanced phase contrast, particularly for low atomic number materials. The XRM image attributes are of particular importance for grey-level phase distinction in mineralogy, geosciences, and materials science applications. The high resolution and phase contrast allow for the distinction of fine-grained phases in multi-component samples, in such applications as process mineralogy, for the identification of micron-sized minerals of economic importance. Additional resources for 2D-3D comparison and calibration methods are provided by Mintek, viz., automated scanning electron microscopy and micro-X-ray fluorescence imaging, as complementary techniques to the 3D X-ray microscopy. An image registration protocol has also been developed to facilitate 2D-3D comparison in assigning grey levels to appropriate minerals/phases in samples. This talk will examine different applications in illustrating the capabilities of the system, with a focus on mineralogy.

Status of Imaging with Radiation at Necsa

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The South African Nuclear Energy Corporation (Necsa) is in the process of establishing a National Centre for Radiography and tomography (NACRAT) that will benefit a wide range of researchers, students, industries and communities in South Africa. The centre will utilize complementary radiation beams such as neutron (cold, thermal, and fast), X-rays and gammas rays. Currently the centre has a well-established facility that has a micro focus X-ray CT scanner. However, the neutron computed tomography facility is still under upgrade. The X-ray CT scan is being utilized to support and fulfil the mandate of Necsa to undertake and promote research and development in the field of material science, nuclear energy, radiation sciences and technology. In the last 10 years, the facility has become a multidisciplinary research facility being utilized for non-destructive testing from disciplines such as; cultural heritage, soil science, energy sector, civil engineering, bio-sciences, metallurgy, and geo-sciences. This talk showcases the capabilities of imaging with radiation at Necsa with respect to instrumentation, software and methodology.

The Introduction of a New Beamline (BM18) at the European Synchrotron and Radiation Facility, its Implications for Material Sciences, Natural and Cultural Heritage, and Biomedical Research Fields

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A new beamline will be operational at the European Synchrotron and Radiation Facility (ESRF), Grenoble, France in 2022. As an associate country of the ESRF, South Africa benefits greatly from the introduction of new systems to the facility. BM18 is a high-throughput, large- field, phase-contrast tomography beamline optimized for hierarchical imaging with the highest level of transversal coherence worldwide for a microtomography beamline, and an unprecedented beam size at such high energy. The BM18 building hosts a 45m long white beam experimental hutch, and an optics hutch with three sets of various attenuators (C, Al, Al2O3, SiO2, Ti, Cu, Mo, Ag, W, Au) for beam attenuation and beam profiling. Different inline monochromator systems based on combinations of refractive lenses and high precision slits have also been implemented to tune the beam power, bandwidth and beam geometry depending on the needs. A high speed chopper in the optic hutch will make possible to fine tune the beam power without changing its spectrum for a precise control of X-ray dose or to reach the low energies. BM18 will have a 35*2crrT2 beam, giving access to a horizontal field of view of 70cm (120cm for low absorption samples). The large sample stage will give access to 250cm vertical field of view and will be able to do multiresolution scans from 200^m to 0.7^m with energy levels of 300 keV at lower resolutions and 120 keV at higher resolutions. These multiresolution capabilities will be made possible through a highly automated detector stage with up to nine different detectors, that will move all along the marble floor of the hutch on airpads, making it possible to cover propagation distances from 0 to 38m. The ESRF has a long history of partnership with South Africa, and together have made many significant contributions to science, particularly within the research fields of palaeontology and palaeoanthropology. The introduction of BM18 offers an unprecedented opportunity for the progression of large-scale, high resolution phase-contrast tomography in a wide range of applications such as material sciences, natural and cultural heritage, and (as demonstrated recently through the research project imaging of organs linked to the covid-19 pandemic) biomedical applications.

Radiation Shielding Design for a Neutron Radiography Facility at a Research Reactor

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A modern neutron radiography (NRAD) facility may utilise a beam with a neutron fluence rate as high as 1E9 crrT-2 s~-1. This necessitates the design of an adequate radiation shielding structure, usually a chamber, i.e. a complete enclosure. Shielding materials with good dose attenuation performance and affordability must be selected. This presentation deals with the radiation shielding design of an upgraded and redesigned NRAD facility at a research reactor. The design-basis beam is specified as having a neutron fluence rate of 1E9 cnT-2 s~-1 and a radius of circa 24 cm. An MCNP6 model of the research reactor was used to calculate the neutron and photon energy spectra of the beam. A second calculation model of the expanded and aligned circular beam entering the NRAD shielded chamber, was used to beam Radiation shielding design for a neutron radiography facility at a research reactor.

Non-Destructive Micro Tomography of Early Triassic Vertebrate Co-prolites from South Africa

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Fossilized faeces, known as coprolites, contain exceptional palaeobiological information. They provide direct information on the diet, feeding behaviours, trophic relationships, parasitism, and digestive systems of extinct organisms. Moreover, because they can selectively preserve the remains of tiny prey items, like arthropods and microvertebrates, they address specific taphonomic deficiencies in the fossil record. Surprisingly, coprolites remain understudied, despite their potential utility in reconstructing ancient ecosystems. Additionally, classical destructive means of investigating coprolites permanently lose critical information. We will provide a preliminary report, based on non-destructive microtomography (micro-CT), on the contents of approximately 40 coprolites from a fossiliferous Early Triassic locality on the farm Driefontein 11 in Free State, South Africa. Fish remains, mostly scales, teeth and unidentified skeletal fragments are the most common inclusions found in the coprolites. Other significant inclusions include bivalve molluscs, marking the second documented occurrence of freshwater bivalves of any kind from the Early Triassic. Terrestrial vertebrate remains, notably jaws and other postcranial fragments are sporadically present. These co-prolites represent the leavings of vertebrates inhabiting terrestrial and freshwater ecosystems that developed in the wake of the end Permian mass extinction. They are therefore a key component of understanding how trophic networks respond to biodiversity crises.

The Inner Ear Lateral Semicircular Canal and Head Posture in Ungulate Mammals

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The orientation of the lateral semicircular canal of the bony labyrinth is habitually used to infer head posture of modern and extinct animals (mammals, birds, archosaurs and early "reptiles"). By placing the plane of the lateral semicircular canal parallel to the horizontal, the 'spontaneous', neutral position of the head would be revealed. It is believed to be influenced by ecology, diet and behaviour (e.g. browsers would hold their head higher than grazers). Though widespread in the literature, this assumption has not been tested on a large sample of mammals, whereas it has been challenged in archosaurs and humans. Using direct field observations of living animals and CT scanning on almost 200 dry skulls representing some 130 ungulate species, the aim of this project is to investigate the orientation of the plane of the lateral semicircular canal and its reliability for the reconstruction of neutral head posture in modern ungulates. Preliminary results indicate that the orientation of the lateral semicircular canal and that of the head are weakly, yet significantly correlated. The lateral canal would be tilted anteriorly 15° in average when the head is held in its "neutral" position. Factors other than head posture may also account for the orientation of the lateral semicircular canal, such as head-butting, body mass and phylogeny.

Comparison of Two Scanning Modalities for Ancestry Estimation using the Mid-facial Skeleton

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Estimating ancestry from skeletal remains is a key component in formulating the biological profile. The mid-facial region of the cranium is one of the most discriminatory skeletal elements in ancestry estimation. In heterogeneous countries like South Africa, innovative techniques need to be established to quantify variation attributable to ancestry differences. The current study explored the efficiency of three-dimensional (3D) surface scanning in evaluating ancestry-related shape variation compared to Micro Computed Tomography (Micro-XCT) scanners using geometric morphometric methods (GMM). Additionally, this study tested the reproducibility of the craniometric landmark placement and the geometric discrepancy between the two modalities. Forty-one crania of Black and White South Africans were assessed using forty-one mid-facial landmarks. Two sets of data were collected from each cranium, namely Micro-XCT scans and 3D surface scans. On both scans of each cranium, forty-one landmarks were manually placed using the Avizo 8.0 software. First, shape analyses were conducted using GMM to assess and compare ancestry-related shape variations obtained from the two scanning modalities. Secondly, parametric (ANOVA) and non-parametric (permutation testing) tests were employed to assess the influence of ancestry on the mid-facial shape variations. A repeatability test was conducted to assess landmark placement re-producibility on both scanning modalities. A General Procrustes Analysis was conducted to obtain orientation-variant shape coordinates. A principal component analysis was also conducted to create independent transformed variables as (principal component scores) to assess ancestry-related shape variations between both scanning modalities. Geometric discrepancies were assessed through the alignment and superimposition of the 3D reconstructions from both scanning modalities. Shape variations between the two scanning modalities were noted to be similar, with statistically significant p-values ($p < 0.001$). Discriminant function analysis (DFA) was used for ancestry classification purposes. A100% classification accuracy was obtained for Black individuals, using Micro-XCT and 3D surface scans. White individuals were correctly classified with 94% accuracy from Micro-XCT scans and 88% from 3D surface scans. Repeatability testing for both intra- and inter-observer error using Micro-XCT scans showed the left and right Orbitale had the highest and Rhinion and Nasomaxillare the lowest dispersion values, respectively. On the 3D surface scans, the left and right Submaxillare curvatures had high dispersion values, with the Zygomatico Superior having the lowest values. The PCA data revealed similar ancestry-related shape variations were observed for both modalities, with analogous overlap between Black and White South Africans. Geometric discrepancies visualization was performed to calculate the surface distances obtained between aligned 3D reconstructions of both 3D scanning modalities using the same specimen. Discrepancies were observed in the area of the Submaxillare curvatures. The visualization of the geometric discrepancies was consistent with the statistical analysis results. This study suggests that 3D surface scanners can be utilized for ancestry estimation using GMM. The introduction of 3D surface scanners may reduce measurement error and may validate ancestry estimation results obtained through the traditional osteometric method can be in a forensic setting. However, more extensive research is required with larger sample size, and more population groups to support the findings from this study.

An Investigation into the Complementary Capabilities of the X-ray Computed Tomography and Hyperspectral Imaging of Drill Core in Geometallurgy

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The effect of ore variability poses a major challenge to the mining and processing industries. Variability arises from heterogeneity in the mineralogy and textures across an ore deposit. The ability to manage this ore variability requires upfront knowledge of the mineralogy and texture ahead of mining and processing, ideally derived from exploration drill cores. As we head towards the fourth industrial revolution (4IR), machine learning and intensive data, there is also a need for automated data derived from drill cores -Ideally, using non-destructive, rapid, and inexpensive automated scanning techniques. Hyperspectral imaging (HSI) is one of the key techniques of automated drill core scanning in geomet-allurgy for mapping problematic minerals in downstream mineral processing, such as the phyllosil-icates. X-ray computed tomography (XCT) provides 3D imaging of drill core yet is more routinely applied in research applications and is dependent on other techniques for mineral identification. Mineral discrimination for XCT also requires sufficient mineral density and attenuation coefficient variation (>6%). This opens an opportunity to couple the two techniques, aiming to address and emphasise the image scanning techniques for drill core in geometallurgy and to provide further knowledge on the practicality of the HSI and XCT in drill core from image acquisition to processing. Ultimately, the aim is to investigate how well the techniques complement each other for mineral and texture identifications and if combined would produce additional information. This was achieved by moving HSI cores to a higher resolution than standard practice. The results showed HSI scanning on the PGE drill core to be challenging because of the dark colour of the core. However, useful information on the alteration mineralogy could still be extracted. On the other hand, XCT produced information on high dense (including the possible PGMs) minerals and mineral association in the cores. However, there has been a challenge to discriminating between grey values (especially of silicates) due to intensive alteration of the rocks. Grouping of minerals (segmentation) needed to be carried out for each rock type. For example, plagioclase and opx were discriminated in less altered rocks (feldspathic pyroxenite and anorthosite) than more altered rocks (altered harzburgite and pegmatoidal pyroxenite). Moreover, with careful scanning parameters and segmentation processes, sufficient information on ore variability can be obtained. Keywords: XCT; HSI; mineralogy; texture.

Applications and scattering effects in Neutron Imaging

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The talk will present the neutron imaging facilities NECTAR and ANTARES at the FRM II research reactor at Heinz Maier-Leibnitz Zentrum of Technical University of Munich, Germany. It will show the available imaging methods with several examples, many of which rely on scattering effects that are rather unfamiliar to the X-ray user, as well as on very different contrast mechanisms.

Nikon Metrology's new 225 kV Micro Focus X-ray CT

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A unique combination of five innovative features has been incorporated into Nikon Metrology's new 225 kV microfocus X-ray CT (computed tomography) system, the XT H 225 ST 2x. As its suffix implies, it offers twice the data acquisition speed and doubles the filament lifetime, considerably extending the system uptime. Doubling inspection productivity raises the system's suitability for quality control (QC) applications on the shop floor, whether in vehicle component manufacture or any serial production environment. It heralds a major increase in factory efficiency by meeting the changing requirements of today's manufacturing sector, whereby QC is starting to drive the operation and optimisation of production lines, an ethos known as Quality 4.0.

Nose Approximation from Cone-Beam Computed Tomography (CBCT) Scans using a New Computer-assisted Method Based on Automatic Land Marking

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Manual facial reconstruction methods require a high degree of anatomical and sculptural expertise and remain difficult and inherently subjective in practice. Additionally, the non-consideration of population specificities, the lack of standardisation and the poor correlations between facial bony structures and facial soft features, also limit objectivity and accuracy of manual reconstructions. In light of a great demand for the identification of unknown remains in South Africa, a need exists to establish reliable facial approximation techniques that take into account sex and age, as well as the South African population. The aim of this study was to provide an automated computer-assisted method to create accurate statistical models for predicting nasal soft-tissue shape from information about the underlying skull substrate using CBCT scans. The database contains 200 cone beam computer tomography scans (CBCT), belonging to 100 black South Africans and 100 white South Africans, they were selected from the Oral and Dental Hospital, University of Pretoria, and the Life Groenkloof Hospital, Pretoria, South Africa. The acquisition and extraction of the 3D relevant anatomical structures (hard- and soft-tissue) were performed by an automated three-dimensional (3D) method based on an automatic dense land marking procedure using MeVisLab © v. 2.7.1 software. An evaluation of shape differences attributed to known factors (ancestry, sex, size and age) was performed using geometric morphometrics, while statistical models of prediction were created using a Projection onto Latent Structures Regression (PLSR) algorithm. The accuracy of the estimated soft-tissue nose was evaluated in terms of metric deviations on training and on un-trained datasets. Our findings demonstrated the influence of factors (sex, ageing and al-lometry) on the variability of the hard- and soft-tissue among two South African population groups. This research provides accurate statistical models optimised by including additional information such as ancestry, sex and age. When using the landmark-to-landmark distances, the prediction errors ranged between 1.769 mm and 2.164 mm for black South Africans at the tip of the nose and the alae, while ranging from 2.068 mm to 2.175 mm for the white subsample. The prediction errors on un-trained data were slightly larger, ranging between 2.139 mm and 2.833 mm for the black South African sample at the tip of the nose and the alae and ranging from 2.575 mm to 2.859 mm for the white South African sample. This research demonstrates the utilisation of an automated three-dimensional (3D) method as a convenient prerequisite for providing valid and reliable nose prediction models independent of any forensic artistic interpretations.

Filling the Olson's Gap? A re-appraisal of Raranimus dashank-ouensis (Synapsida, Therapsida) using CT Scanning Technologies

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Non-mammalian Therapsida is a paraphyletic group of Permian-Jurassic amniotes closely related to mammals. Understanding the origin of Therapsida is complicated by the existence of a phylogenetic gap in the fossil record termed Olson's gap. Because of its assumed low stratigraphic occurrence and basal phylogenetic position, Raranimus dashankouensis, from the Dashankou fauna, Qingtoushan Formation, China, is the best candidate to fill this gap. However, its phylogenetic position as the basal-most therapsid is the subject of debate. In addition, the age of the Qingtoushan Formation is poorly constrained. Enhancement of CT scanning technology offers new ways to investigate the skull of extinct species and provides access to characters which were previously out of reach (e.g. internal cranial features such as cranial nerves) which can be useful for phylogenetic analysis. Our results show that Raran-imus has five therapsid synapomorphies, the most obvious being the short contact between the maxilla and the prefrontal. However the presence of plesiomorphic characters, such as the presence of a precanine caniniform tooth, manifest retention of typical "pelycosaur" grade features. The maxillary canal morphology of Raranimus is comparable to that of the "pelycosaur" Varanosaurus and the biarmosuchian Herpetoskylax. Overall, this suggests a very basal position for Raranimus in the therapsid phylogenetic tree. New data on the age of the Qingtoushan Formation indicates a Roadian age for Rarianimus, hence filling the Olson's gap and confirming that the genus is an important taxon for understanding the evolutionary origin of therapsids. The project is financially supported by the National Research Foundation, the DST-NRF Centre of Excellence in Palaeosciences, the Palaeontological Scientific Trust (PAST), and the Postgraduate Merit Award program of the University of the Witwatersrand, Johannesburg, South Africa.

Computed Tomography Reconstruction for the Reduction of the Effects of Metallic Inclusion

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X-ray Computed tomography (XCT) is a technique that is used to generate 3D images of a sample which allows the observation of the internal structure. Projections are collected as the sample rotates through 360 degrees followed by a reconstruction step using algorithms such as the filtered back-projection. This technique has found widespread applications in fields such as medical diagnostics, palaeontology, geology, anatomical science and materials science. Samples with high-density inclusions can produce data with artefacts, such as streaks and noise we report an investigation on the effects of adding an image processing step before performing computed tomography reconstructions. We have acquired projections with a micro-computed tomography scanner and carried out image processing functions for the improvement of the quality of the data output. We have obtained a paleontological specimen with a significant amount of iron inclusions which cause bright and dark streak artefacts. We have applied several filters to alter the projections before reconstruction. The results so far show that the minimum filter, median and median filter reduces the noise and streak artefacts in the specimen. The Gaussian smoothing filter also successfully reduces the noise in the images, but the streak artefacts are still significantly visible. The unsharp mask filter enhances the edges in the images and reduces the streak artefacts significantly. However, this filter in nature enhances other high-frequency components in an image, and as such, the noise is also accentuated. We also report the use of alternative reconstruction algorithms using the ASTRA toolbox to reduce the effects of high-density inclusions.

65 Years of Using X-rays to Study Tooth Replacement in Therap-sida

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The widespread adoption and implementation of three-dimensional (3-D) imaging techniques has had an enormous impact in palaeontology. Researchers now have access to delicate internal cranial structures (e.g., maxillary canals, inner ear labyrinths, and unerupted dentition) that were not available to their predecessors in such immaculate detail. In the past, these structures would only have been accessible through destructive techniques, and indeed, the earliest studies of therapsid tooth replacement relied upon such practices. These earliest studies employed either the process of serial grinding of specimens, or physical breaks in the specimen to expose the unerupted teeth within the bone. Due to the destructive nature, these studies could only be undertaken once—and usually on well preserved individuals to minimise the loss of additional specimens—and each specimen could only be sampled in a single direction (i.e, sagittal, coronal, transverse). In addition to the entire specimen being destroyed, a small amount of information, dependent on the thickness of the cutting blade, was lost during the sectioning process. Medical X-rays were first used to image the dentition of therapsids from the South African Karoo in a detailed study of the tooth replacement patterns in Gorgonopsia and Therocephalia published 65 years ago by Kermack. Although these early images only allowed for the unerupted teeth to be viewed in a single plane, they had the distinct advantage of being non-destructive. By making radiographs of various specimens in lateral view, Kermack was able to describe the root morphologies of the canines, and demonstrate that basal theriodonts retained the ancestral condition of two maxillary canines. Recent advances in imaging techniques, including the development of computed microtomography (pCT), as well as the establishment of three dedicated pCT facilities at South African research institutes (NECSA, Stellenbosch University, and Wits University) has allowed for Karoo fossils to be imaged, reconstructed, visualised, and prepared virtually. The non-destructive nature of pCT, makes it possible for studies to include multiple individuals of the same taxon. Often these individuals are of different sizes so as to sample an inferred ontogenetic sequence (e.g., *Thrinaxodon liorhinus* and *Galesaurus planiceps).* Inclusion of multiple individuals has allowed for a wider range of tooth developmental stages to be observed, further enabling the inference of replacement patterns, and facilitating the estimation of the number of times a tooth at a particular position in the jaw was replaced during an animal's lifespan. The non-destructive nature of X-ray imaging has also allowed for the inclusion of holotypes (e.g., *Euchambersia mirabilis* and *Lycosuchus vanderrieti),* which is important as several therapsids from the Karoo are only known from a handful of specimens (e.g., *Euchambersia mirabilis).* As synchrotron radiation becomes increasingly more accessible to South African scientists, we are poised to gain an even greater understanding of the mechanisms of tooth replacement of our distant ancestors. Synchrotron radiation allows for sub-micron resolution of developing teeth, permitting the determination of individual lines of enamel deposition in tooth crowns. Such information may grant insight into the timing of initiation of development of a replacement tooth relative to the functional predecessor.

Did Australopithecines and Homo Taxas Suffered from Alveolar Bone Loss, which may have affected Masticatory Functions?

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The primitiveness of the craniate and masticatory craniofacial apparatus and the evolution of the multifunctional capacity of all amniotes' clades has been controlled by several yet ancestral common genes to finally sculpt a true thecodont attachment apparatus with cementum, periodontal ligament fibres inserting into the alveolar bone. The evolution of the masticatory apparatus with its supportive periodontal structures has been Nature's complex yet highly successful evolutionary challenges to provide proper functional and mechanical support during mastication, deglutition, copulation as well as numerous other physiological functions of life not least the extraordinary power of the human smile. Australopitecus africanus, A. robustus and Homo gnathic remains (7, 5 and 6) were additionally examined by micro-focus X-ray computer tomography housed at NECSA. Scans were performed at 140 kV and 70 uA, and at 160 kV and 70 uA, respectively. The latter scans allowed for a spatial resolution of 34 um. The reconstruction process transformed the 2D projection images into a 3D virtual volume. In systematic observations of the fossilized gnathic remains of early hominine of Southern Africa, we observed alveolar bone loss affecting Australopithecus africanus and A. ro-bustus as well as Homo species. Alveolar bone loss with the inferred indication ofacute and chronic periodontitis is the first recognized disease in hominid evolution. There is however, a transition of morphological events from the Australopithecines taxa to the emerging Homo species, such as Homo habilis and Homo erectus unearthed in the Cradle of Mankind, Blauwbank Valley, Swartkrans and Sterkfontein, South Africa. Homo species show the evidence of alveolar bone loss with the emergence of a vertical component of attachment loss with crateriform inter-radicular osseous lesions, as found in extant Homo, defining chronic periodontitis in Homo sapiens. Vertical components of bone loss were not seen in both A. africanus and A. robustus taxa raising the question of what would be the evolutionary significance of alveolar bone loss in early Homo species.

Microfossil Evaluation using X-ray Computed Tomography for Petroleum Exploration

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The application of micropaleontology in petroleum exploration is an essential tool with a pivotal role in the success of the oil and gas industry over the decade. In petroleum exploration, this subdivision of palaeontology is based on the taxonomical identification of microfossils to determine drilling casing and coring points by monitoring the biostratigraphy encountered and confirm the total drilling depth, reducing unnecessary drilling and expenses. The current bulk processing and identification of microfossils from drill cores for petroleum exploration are limited by traditional chemical and physical microfossil extraction and microscope inspection methods. These traditional methods of extracting microfossils are time-consuming and damage microfossils, affecting the evaluation and correlation with biostratigraphy reports. This study discusses and demonstrates the potential of X-ray tomography (Micro CT) to add value in the process chain of microfossil characterisation for petroleum exploration by subjecting drill core samples to micro CT scans at different extraction stages. The results show that X-ray tomography can be used as a non-destructive technique to characterise microfossils in-situ while providing the 3D architecture and distribution. The additional 3D information is not only useful but is easily automated and recorded for future use.

Characterizing the Unusual 3D Morphology of Calcite Minerals found in Coal: A Case Study

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Although there has been a shift towards cleaner energy production (e.g. biomass and solar), these energy sources won't entirely replace fossil fuels in the near future. Thus, low grade coal will remain the dominant contributor to the South African power grid for the foreseeable future. Such coals have abundant mineral matter that causes complications during coal utilization. This case study aimed to characterize the chemistry, mode of occurrence and formation of minerals in a sub-bituminous coal sample. X-ray micro-computed tomography (CT) contrasts caused the minerals to appear brighter (i.e. denser) than the surrounding matter and similar greyscale variations were also observed with Scanning Electron Microscopy (SEM) imaging. The non-destructive ability of X-ray CT provided 3D visualization of the minerals' morphology which led to the identification of unusual star-shaped minerals. Energy-dispersive X-ray spectroscopy (EDS/EDX) analysis classified the star-shaped minerals as calcite. Although it's rare, biogenic processes can form carbonate minerals in coal which led to noticing the resemblance between the mineralogical structure of the calcite star-shaped minerals and that of calcareous sponge spicules.

Positron Emission Imaging

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Imaging techniques that employ radio-tracers have application in the medical industry through Positron Emission Tomography (PET), which focusses on identifying the presence of cancers, blood flow, chemical composition and identifying changes in metabolic processes. The development of Positron Emission Particle Tracking (PEPT) has increased the scope of application to measure particle behaviour in flowing and granular systems, with specific applications in tumbling mills and flowing systems that have potential impact in an industrial setting. PET and PEPT results obtained from experiments conducted at PCIF/NUMERI (Necsa) and UCT/iThemba-LABS respectively, will be presented showcase the effectiveness of this emission radiography technique. Furthermore, results acquired using PEPT will be compared to results acquired when using Fast Neutron Radiography (FNR), highlighting the complementary information observed between these two techniques.

Scales, Lips or Venom? A Survey of the Trigeminal Canals in Tyran-Nosaurus Rex using X-ray Computed Tomography

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Since the late nineteen-nineties, 3D imaging occupies a place of its own in evolutionary studies, including palaeontology. In this study, we used X-ray Computed tomography (CT) to study in 3D the snout neurovascular system of one of the most famous theropod dinosaur, Tyrannosaurus rex. Our work highlights the stunning complexity of the three main branches of the trigeminal canal system that ensured the sensitivity of the snout. The trigeminal canal of T. rex shares a lot of similarities with that of crocodiles, especially maxillary ramus, although, in contrast to most archosaurs, the ophthalmic branch is extremely developed. The vomeronasal organ appears very large, which is consistent with the large size of the olfactory bulbs and underlines the importance of olfaction in tyrannosaurids. Comparisons are made with CT scans of an iguana and monitor lizard to evaluate the hypothetical presence of a venomous organ in Tyrannosaurus rex. The debates over the proposed presence of lips in theropods in also discussed.

Bakeng se Afrika - A Digital Skeletal Repository, for Africa, by Africa

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Micro-focus X-ray computed tomography (micro-XCT) is the gold standard modality for microstruc-tural assessment of skeletal remains for the purposes of clinical research. Micro-XCT renders high-resolution results non-invasively, enabling researchers to collect data on the micro-inner structure of odonto-skeletal elements. Micro-XCT scanning also allows researchers to digitally preserve skeletal remains for future use in research and education. Bakeng se Afrika is a European Union (EU) co-funded project with the goal of creating a digital repository of micro-XCT scanned skeletal elements of South African individuals. Skeletal remains from the University of Pretoria, Sefako Makgatho Health Sciences University and Stellenbosch University were scanned at Necsa in Pelindaba and the X-sight facility in Cape Town. Data was then curated by the Bakeng se Afrika team to create an internationally accessible repository of digital skeletal remains accompanied by a series of Standard Operating Procedures (SOP) on 3D imaging. The Bakeng se Afrika digital skeletal repository will launch in November 2021 and will be accessible via the University of Pretoria's Figshare platform. The data is applicable to a wide variety of research topics, including, but not limited to: dentistry, clinical anatomy, biological anthropology, forensic anthropology and palaeoanthropology. Join the Project Manager of Bakeng se Afrika for a talk on the inception of Bakeng se Afrika, its uses in research so far, and the exciting prospects on the horizon.

Online Vision Assistant Optimization of Neutron Radiography Detector System Optical Parameters

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Quality of radiographs acquired using the Charged Couple Device (CCD) camera based Neutron Radiography (NRAD) detector system is easily compromised by level of precision of the detector system optical parameters setups. Manual adjustment to optical parameters comprising the Field of View (FOV) and focusing is a tedious time consuming process which also expose the detector system components to possible damage. These raise a demand to exercise care when working with detector system's components, which also, takes time. The resulting effect is that, much time is spent in the radiological environment on setups than doing the actual experiments and the radiation safety of the operators is compromised as a result. We propose the upgrade of the current detector system at SAFARI-1's NRAD facility to include automation of the detector systems' optical setups using image processing algorithm and the electronic micro adjustment devices to eradicate the time consuming process and to improve the safety of the operators. Simulations were conducted to uncover the performance and robustness of the image processing algorithm. This talk will cover the work being done to upgrade the detector system to maximize the image quality and minimize the adjustment turnaround time.

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