CTLAB
X-ray Computed Tomography

BRNO UNIVERSITY OF TECHNOLOGY

NEWSLETTER
AUTUMN 2017

FOREWORD

Dear Readers and Friends,

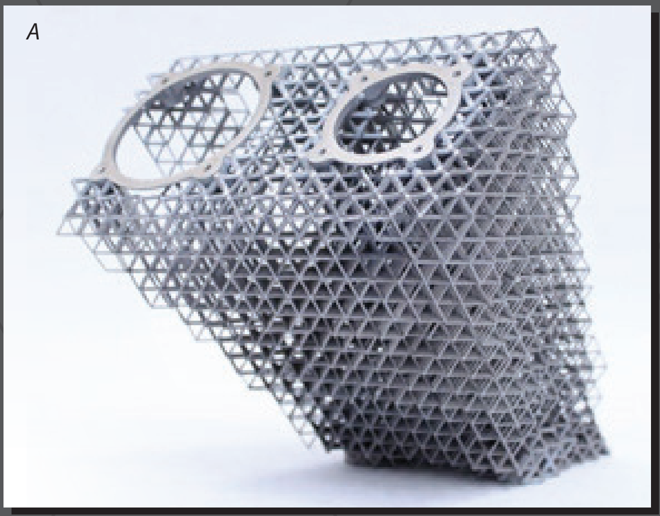
I am delighted to introduce the first issue of our laboratory newsletter released in English. By this way we would like to keep you updated on recent activities of our Laboratory of computed tomography in the Central European Institute of Technology (CEITEC) at Brno University of Technology.
At the beginning of this year, our laboratory was accredited according to standards CSN EN ISO/IEC 17025 by the Czech Accreditation Institute. Based on this accreditation, we are the first testing laboratory in the Czech Republic which is authorized to perform tests using X-ray computed tomography.
Last summer, our newest device - Rigaku Nano3DX tomograph - was upgraded by replacing the detector. It enables us to observe time-varying events in the future. We also continue to cooperate with the TU Brno Racing student team which achieved excellent results in the world competition and rank among the world's top with their car Dragon 6.

We look forward to further cooperation with you. Enjoy the reading!

Tomas Zikmund
Head of the laboratory

Structural Mechanics Simulation Module

One of our most recent news is connected to the VG studio MAX 3.0 software. It is now able to predict mechanical properties directly on CT data. The Structural Mechanics Simulation (SMS) module allowed our colleagues to test it in a demo version. The advantage of this software comparing to other finite element (FEM) software is the inclusion of real geometry with internal defects of a material (pores and cracks) because these material defects could significantly impair the mechanical properties of a component. Thanks to this module, we can verify whether a component with detected internal defects still resists the required load.



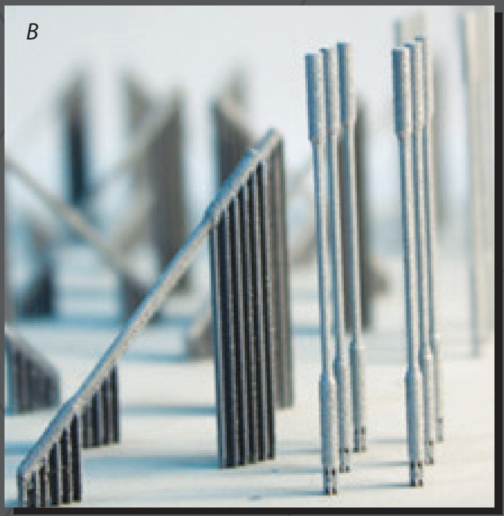


Fig. 1: Ultra light satellite antenna console (A) consisting of a micro-beam structure (B).

The module was tested during a prediction of the mechanical properties of super-light constructions which are made using 3D metal printing. The testing was carried out in cooperation with colleagues from the Institute of Mechanical Design, Reverse Engineering and Additive Technologies department, Faculty of Mechanical Engineering at Brno University of Technology. These micro-truss constructions are designed primarily for the use in the space and aircraft industries and are made up of a system of very thin trusses with dimensions in tenths of a millimetre. During their production, some internal defects in individual trusses might be created. These defects could make the truss' cross section even a half smaller comparing to the original size of the cross-section. This feature negatively influences the mechanical properties of the whole structure.

We also tested special „truss" tensile specimens, which represented the real trusses in a super-light construction. The tensile specimens were virtually loaded down in a SMS module where we examined the influence of a voxel mesh resolution on the results. The specimens were mechanically tested in order to verify the results. Thanks to the SMS module, it was possible to locate the point of the truss breaking correctly and determine the reduction in mechanical properties.

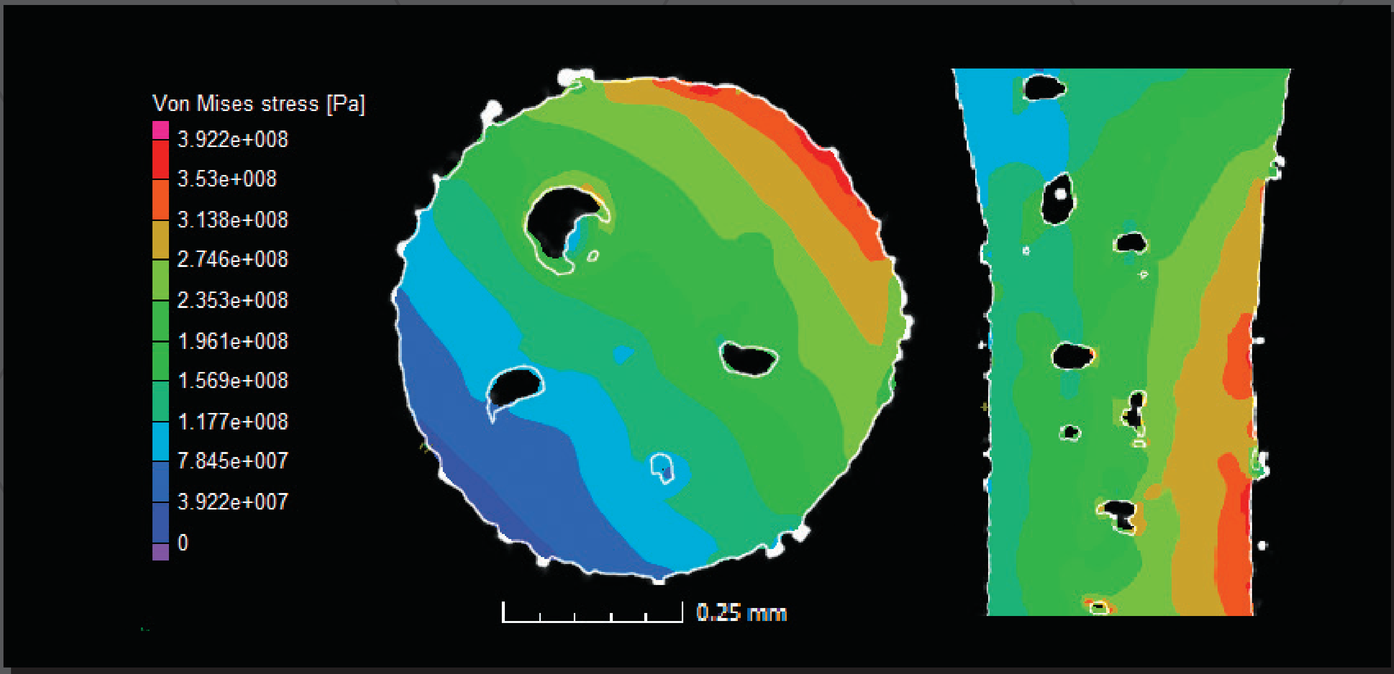


Fig. 2: Application of the presented module in VG Study MAX 3.0. A color-coded simulation of a sample stroke. Transversal cross-section through the rod (left), longitudinal (right).

Imaging technique PET/CT

Positron emission tomography (PET) in connection with computed tomography (CT) is the fastest developing hybrid imaging technique. PET/CT devices are used especially in health care for a biological tissues' imaging. These two techniques are combined because the CT images an anatomical structure while the PET displays a functional examination of tissues. This means that during one examination it is possible to get some information about two things in just one picture: information not only about the morphology but also about the metabolism of the investigated organ.

During an examination, some radiopharmaceutical (fluorodeoxyglucose marked with ^{18}F isotope is used the most commonly) is given to the patient. In the case of a PET examination, the radiopharmaceuticals radiate positrons participating in a formation of the final image. Radiated positrons react (annihilate) with the electrons inside the patient's body. Both particles disintegrate to produce two photons radiated in opposite direction with energy of 511keV (i.e. gamma rays). These photons are detected by a ring of detectors (to see Fig. 3). The exact location of photons' origin is subsequently evaluated on the basis of a time delay between detections of the first and the second photon. After having recorded a sufficient amount of photons from the whole observed volume of tissue and after a reconstruction, a 3D image is created. Pathological phenomena in the patient's body can be observed thanks to the fact that the used radiopharmaceuticals contain glucose which has a specific affinity with the pathological tissue. This affinity is caused by an increased metabolism rate. Due to the increased metabolism rate in locations with pathological tissue there is also an increased consumption of glucose in these locations. Consequently, this signifies an increased activity of the radiopharmaceutical recorded in PET data.

The result of a measuring by PET/CT technique is a fusion of images obtained by both PET and CT devices. The final image carries the information about the function and the accurate position of examined tissues. (Fig. 4)

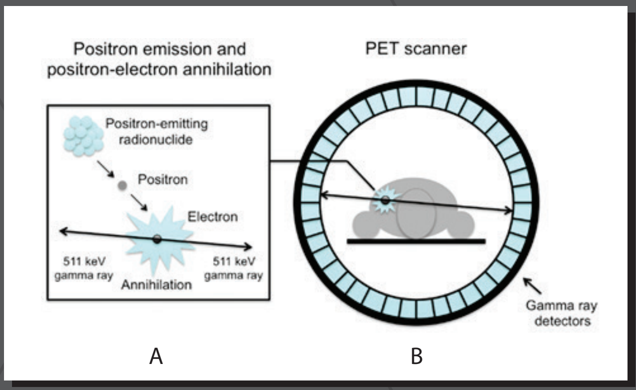


Fig. 3: (A) describes an annihilation of positron with electron and genesis of two photons with energy of 511keV, (B) positioning a patient in a PET device and the ring detector used for recording gamma rays. [1]

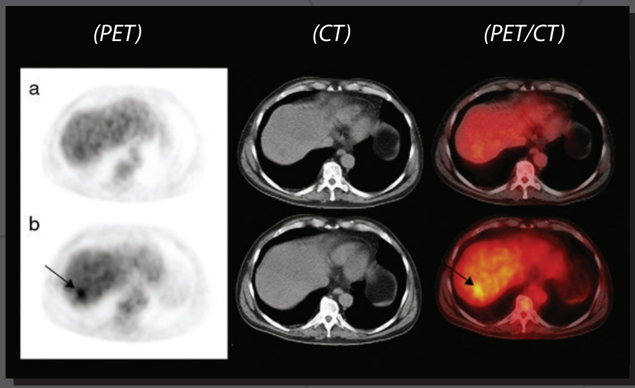


Fig. 4: PET, CT and fusion of PET/CT images of axial slices in the liver (a) physiological, (b) with metastasis. [2]

Usage of PET/CT devices in medical science [3]:

- In oncology for detection of a tumor deposit.
- In neurology for determination of a brain area responsible for epileptic fits; for discovery of degenerative brain diseases, for example Alzheimer's disease; and for examination of brain in case it is affected by a tumor.
- In cardiology, for differentiation of the viable parts of heart muscle from the necrotic parts, for example after a heart attack.

[1] Van Der Veldt Astrid, Smit Egbert, Lammertsma Adriaan: Positron Emission Tomography as a Method for Measuring Drug Delivery to Tumors in vivo: The Example of [11C] docetaxel. Frontiers in Oncology (2013) vol. 3 p. 208, doi: 10.3389/fonc.2013.00208

[2] D. Fuster et al.: Dual-time point images of the liver with 18F-FDG PET/CT in suspected recurrence from colorectal cancer. Rev Esp Med Nucl Imagen Mol. (2012) vol. 31(3) p. 111–116

[3] Masaryk Memorial Cancer Institute (Brno, Czech Republic), Investigation and Examination Techniques, PET/CT, https://www.mou.cz/pet-ct/t4330

Interpretation of tomographic data

The output of tomographic measurements is a series of gray-tone images. Image pixels carry volume information, therefore they are called voxels (see Newsletter 1). The gray value of each voxel represents the absorption of X-rays passing through a given place in the sample. The absorption properties of these regions depend on the density of the material. In tomographic slices, dense materials (such as metals) are represented by light color and thin materials (eg. air, polymers) by dark color. State of the art detectors measure the intensity of the radiation with a 16-bit dynamic range (216, i.e. 65,536 shades of gray). Although the data for analysis are processed in 16-bit depth, they are displayed in only 8-bit depth on the monitor. For this purpose, mostly a linear function is applied on a selected part of the histogram of intensities representing the sample (transformation function).

CT data are provided to users in the .vgl format which can be opened in the MyVGL viewer (Fig. 5). We provide this software in addition to the data. It allows viewing tomographic slices in three orthogonal views. Additionally, data can be displayed in 3D after using rendering tools. This software enables a user to measure linear dimensions, save the selected view into the image, and view the analyses performed in the full version of the software. Instead of .vgl format, CT data can be provided to customer in the form of a series of standard formats (PNG, TIFF, DICOM) that can be viewed in a classic image viewer. The size of the output file of tomographic data from one measurement is up to 20 GB depending on the size of the sample and the number of performed analyses. With respect to the data size, users have to work with the data on a computing station with sufficient operation memory.

The 3D model of the object is exported to a lithographic STL format (so-called dot cloud), which could be used in various CAD softwares (Inventor, Catia, Solidworks, GOM Inspect) or used for example for 3D printers. A conversion of the STL model to the STP, STEP (which depict the model by a set of geometric formations) is realized in Geomegic, Tebis software and often requires manual intervention by the operator.

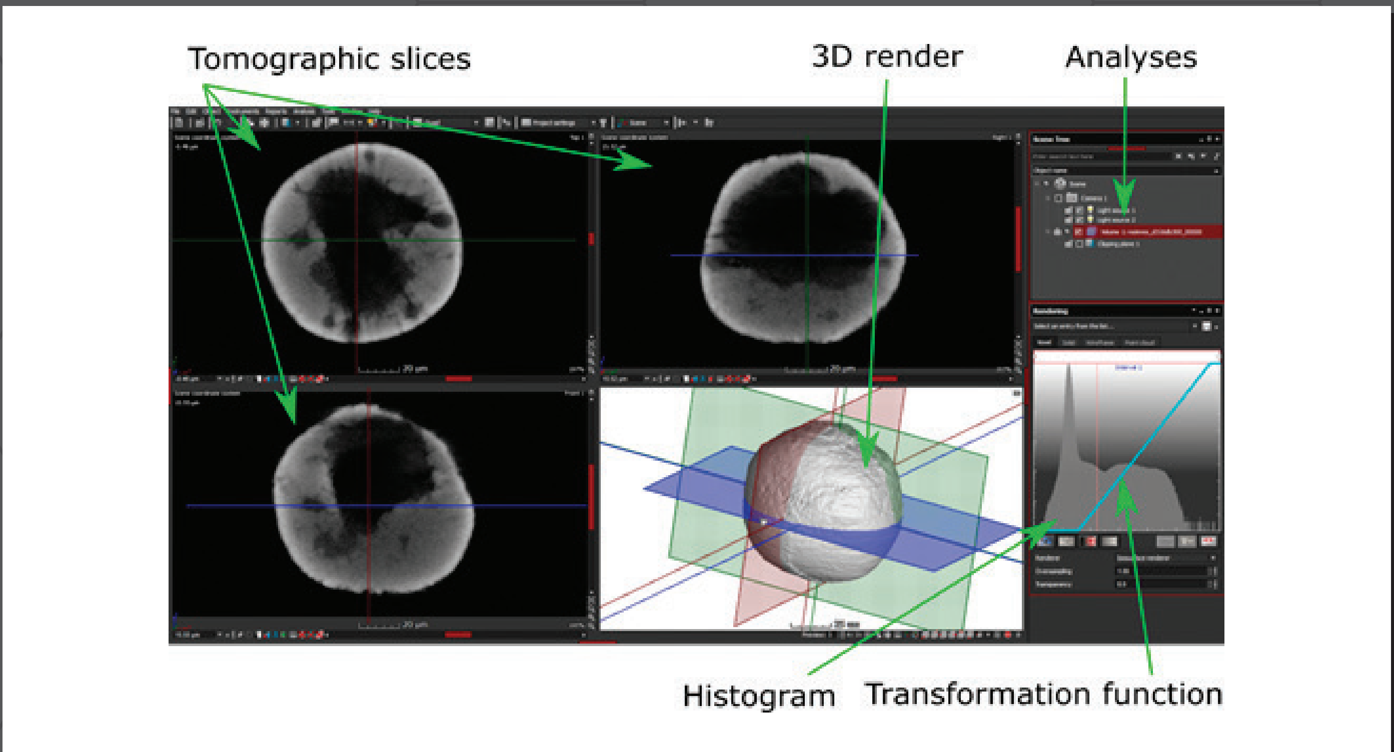


Fig. 5: Free viewer of tomographic data MyVGL.

Analysis of glued joints for TU Brno Racing

In the last issue of our Newsletter we already informed you about our collaboration with the student team TU Brno Racing, from BUT, on the development of their new formula car. During this collaboration our laboratory was involved in the development of used composite parts.

Specifically, we conducted a non-destructive analysis of glued joints between carbon fibre pipes and aluminium ending part that were used for a new suspension system (Fig. 6). These glued joints had been analysed before and after the dynamic tests. Which means it was possible to evaluate an effect of strain on their inner structure. It was found out that defects were present in analysed inner structures (Fig. 7), but dynamic tests did not lead to an expansion of the defects or to a creation of new ones. Acquired CT data had to be analysed visually because the used glue and composite material had almost the same absorption properties for X-ray radiation (they cannot be reliably differentiated based on intensity information). They only differ from each other in terms of their inner structure. It was also discovered that the glue did not properly adhere to the aluminium part around its entire surface. This experiment confirmed that functionality and properties of the analysed parts were not limited by discovered defects.

By carrying out the CT analysis it was possible to verify the technological process used for production of these parts and eventually reveal rejects. The analysis, therefore, significantly contributed to a total reliability and safety of the new formula car.

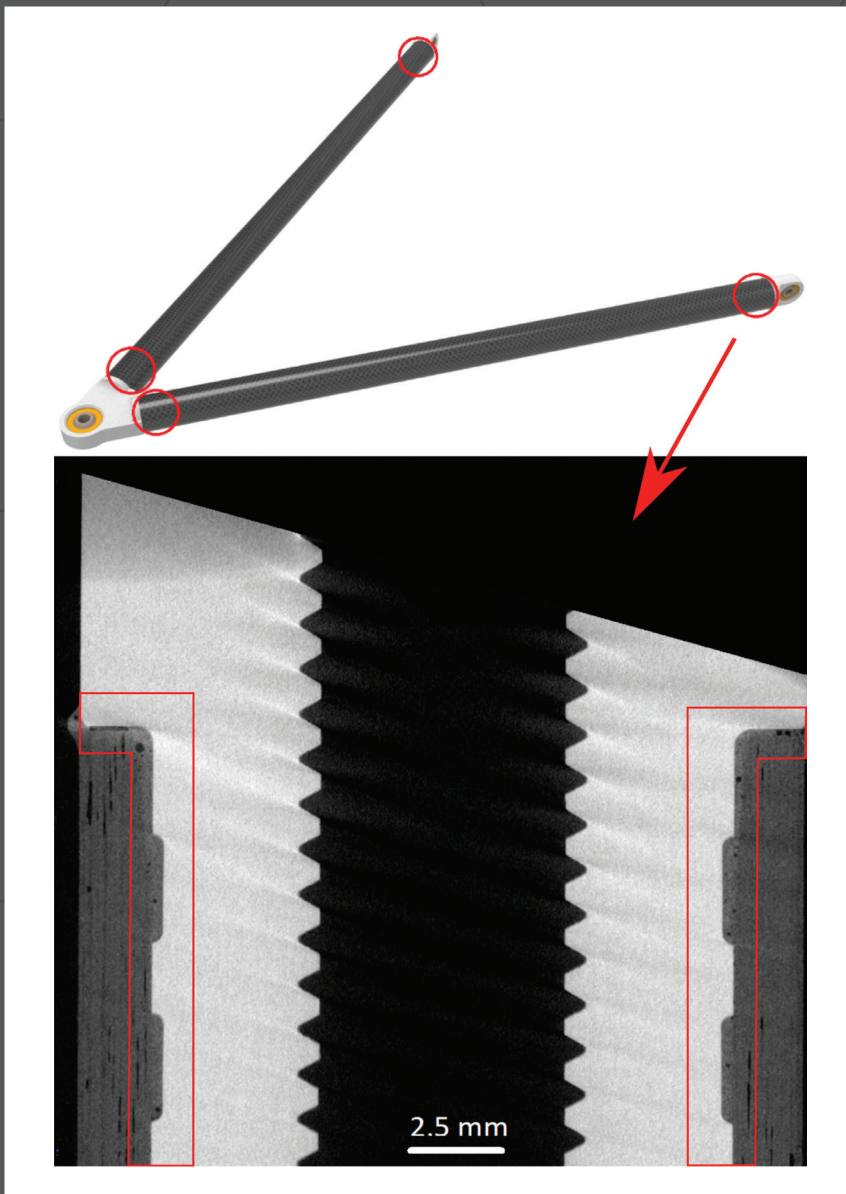


Fig. 6: Visualization of analysed part of suspension system (upper part of the figure) with highlighted areas that were subject of CT measurement and subsequent analysis. In the bottom of the image the example of longitudinal CT slice from one of the analysed areas is shown with highlighted area of glued joint between aluminium and composite part.

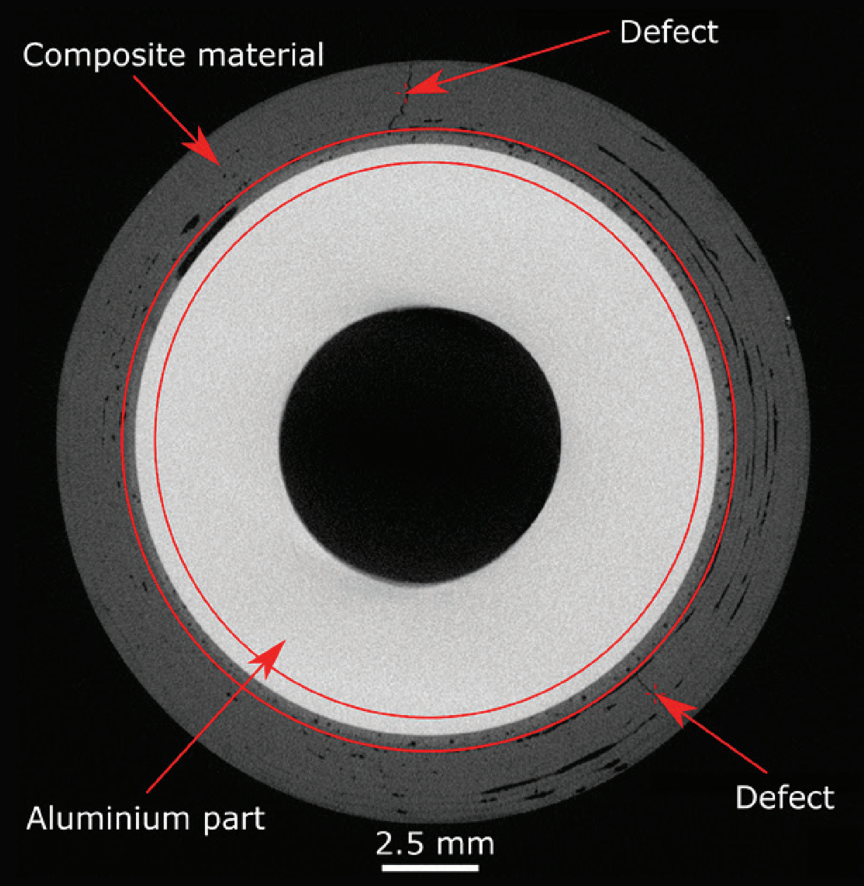


Fig. 7: Example of orthogonal slice from one of the analysed areas with highlighted area of glued joint between aluminium and composite part and also the discovered defects in inner structure of this composite material.

Video presentation about the involvement of our laboratory in this project can be seen here: https://www.facebook.com/tubrnoracing/videos/1624957544194815/.

3D visualization of cellular structures not only for computed tomography

Data processing and data analysis are still one of the greatest challenges for creating 3D models of the studied samples. This is a general true not only for the data obtained by X-ray computed tomography. Scientists in our laboratory cooperate with other research groups on segmentation and visualization of the data. Imaging techniques enabling 3D imaging are e.g. magnetic resonance imaging (MRI) or electron microscopy. One of our latest publication focuses on an analysis of cellular structures that were recorded by a transmission electron microscope (TEM) from Tescan company. We participated in the publishing of a chapter in the book 3D Cell Culture, Methods and Protocols (Springers). This chapter methodologically describes preparation of the cell cultures, their

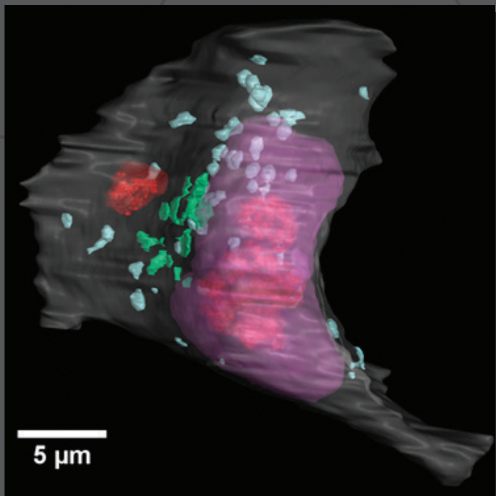


Fig. 8: 3D visualization of one of the cells of the spheroid. Cytoplasmatic membrane creates the boundary of a cell (gray), nucleus (magenta), nucleolus (red), dictyosomes of Golgi complex (green), secondary lysosome (blue).

staining, the experiment on the TEM, data processing with segmentation and the 3D visualization. The described technique is efficient for a detailed morphological analysis of stem cells' spheroid. Such systems are suitable for simulations of relevant environment for modelling diseases and influence of the medication. This approach is becoming more and more popular in regenerative medicine and it is replacing classical 2D imaging techniques that are not able to characterize the cellular structures' complexity.

More: https://link.springer.com/protocol/10.1007%2F978-1-4939-7021-6_30

Publication in Journal of Dental Research

Our co-workers in Institute of Animal Physiology and Genetics AS CR, v. v. i. have been engaged in a long term research of odontogenesis and development of craniofacial structures. Transmembrane protein tmem 107 is one of the proteins whose mutation causes serious craniofacial and palate defects. Our laboratory participated in a paper dealing with the research function of tmem107 protein and description of phenotype of mice with null mutation. This paper was published in Journal of Dental Research (doi: 10.1177/0022034517732538). We contributed with images of 3D models of ossification centers located in the skull of mutant and wild type mice embryos. A comparison of those models led to a description of developmental defects and it was possible to describe atypical position of tongue in a mutant mouse based on the representative tomographic sections.

LATEST NEWS

Modernization of nanoCT station

Nanotomographic device RIGAKU Nano3DX has been recently upgraded with a detector based on a sCMOS chip and with a new control and visualization software. The detector has dimensions of 2048 px × 2048 px and a dynamic range 16 bit. Furthermore, two sets of optical heads with the effective pixel size 0.64 μm and 1.28 μm were acquired, which enables the user to choose from a larger variety of pixel sizes and fields of view. Thanks to this improvement, the device is now capable of more variability and a faster acquisition time. It allows to record faster processes and to reach higher quality data, which brings more possibilities to apply the tomography in fields of biodegradable materials, composites, fibre reinforced polymers etc.

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