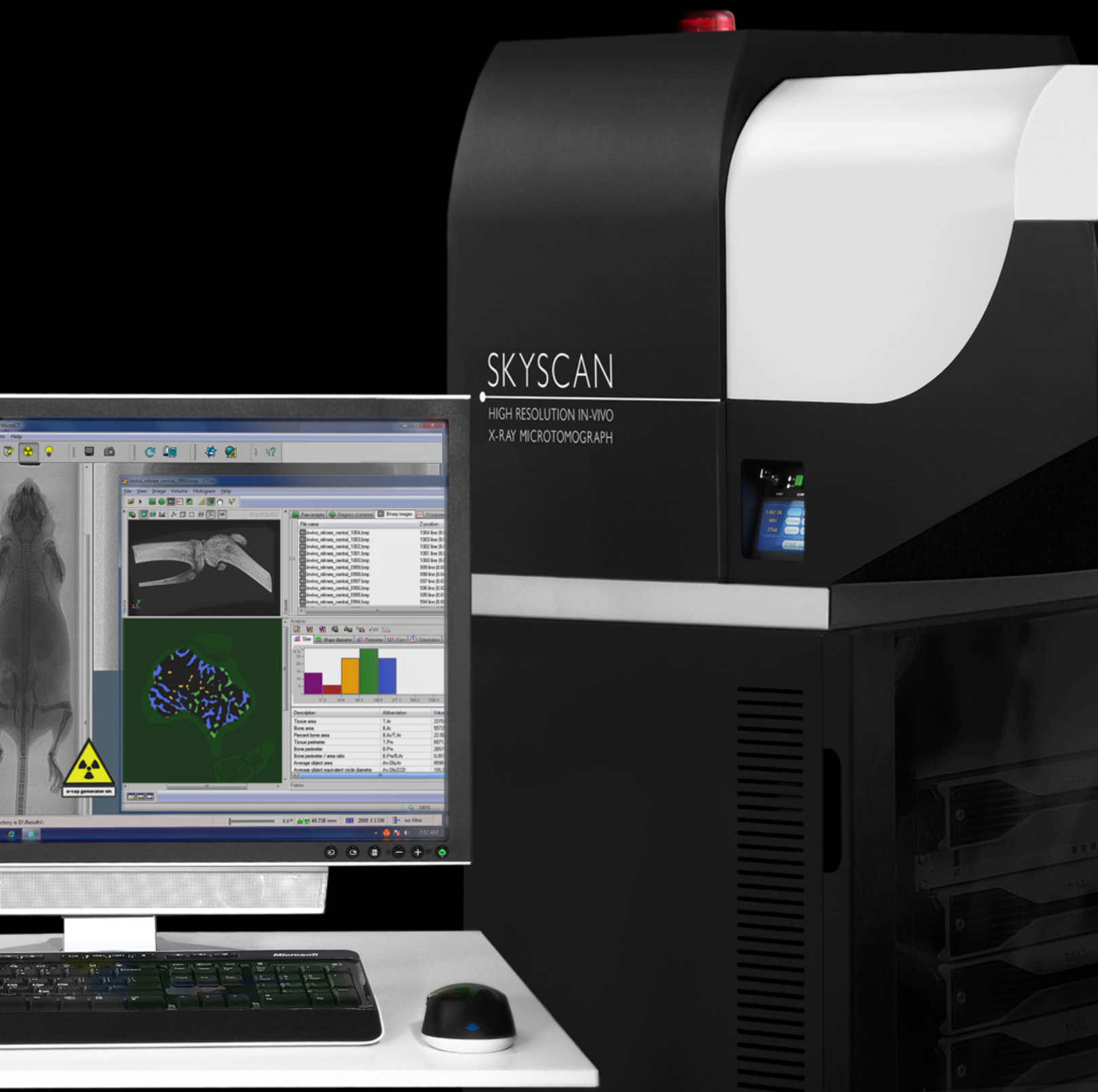
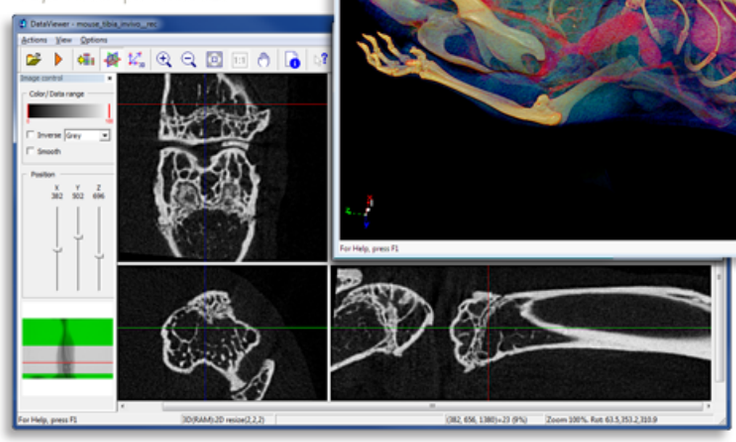
SkyScan1176 high-resolution *in-vivo* micro-CT



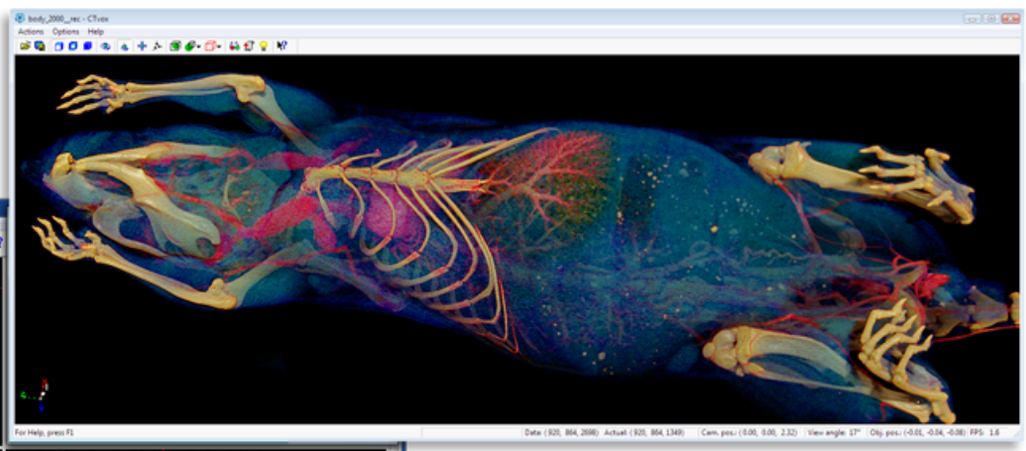
The SkyScan 1176 is a high-resolution low-dose X-ray scanner for in-vivo 3D-reconstruction with details detectability down to 9 microns inside small laboratory animals (rats, mice, rabbit's periphery, etc.). It allows non-invasive reconstruction of any cross section(s) through the animal body and conversion of reconstructed datasets into realistic 3D-images, plus calculation of internal morphometric parameters including bone architectural parameters.

FEATURES

- ☑ up to 8000x8000 pixels in every slice,
- ☑ down to 9μm in-vivo 3D spatial resolution,
- ☑ single computer or cluster cone-beam reconstruction,
- ☑ less than one minute full scanning cycle (for 1Kx1K slice format),
- ☑ scanner control by force-sensitive touchscreen responsive to hands in gloves,
- ☑ full body mouse /rat scanning and distal limb scanning for big animals, such as rabbits,
- ☑ integrated physiological monitoring (page16) for gating and time-resolved tomography,
- ☑ software for 2D/3D image analysis, bone morphometry and realistic visualization.



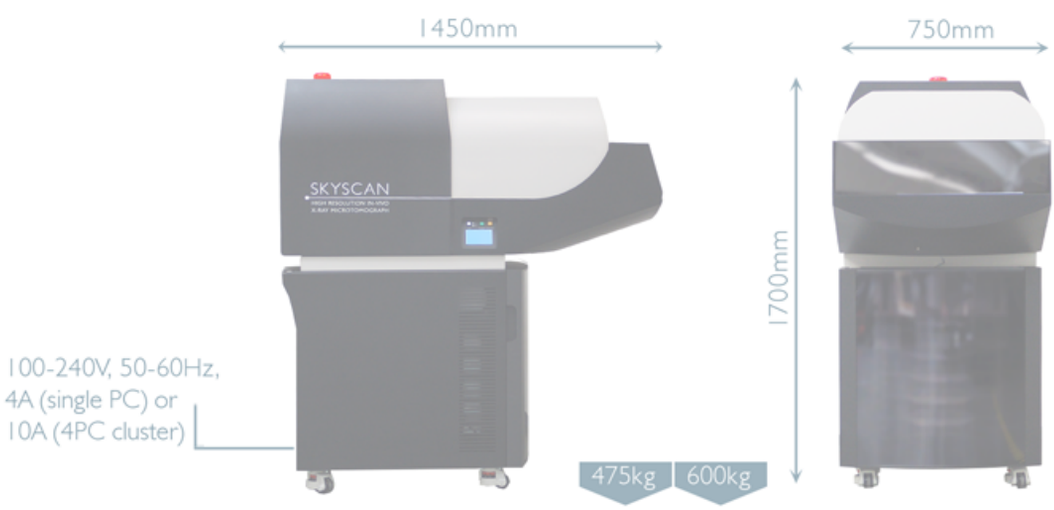
in vivo scan of a mouse knee, 8.7μm isotropic voxel size

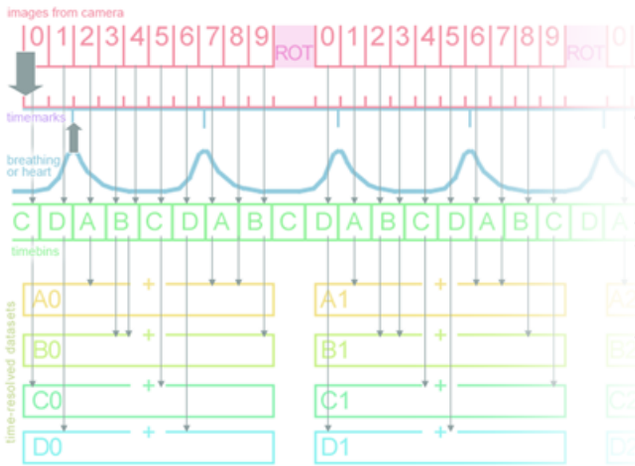


full body scan of a mouse using contrast agent

SPECIFICATIONS

X-ray source ..... 20-90kV / 25W, 6-position automatic filter changer
X-ray detector ..... 11Mp cooled 12bit CCD fiber-optically coupled to scintillator
3D spatial resolution .... 9/18/35μm detail detectability, <16μm low contrast resolution
Scanning volume ..... 68/35mm in diameter, 200mm in length (24 mm in one scan),
Reconstruction ..... cone-beam reconstruction by single PC or internal cluster
Radiation safety ..... <1μSv / h at any point on the instrument's surface

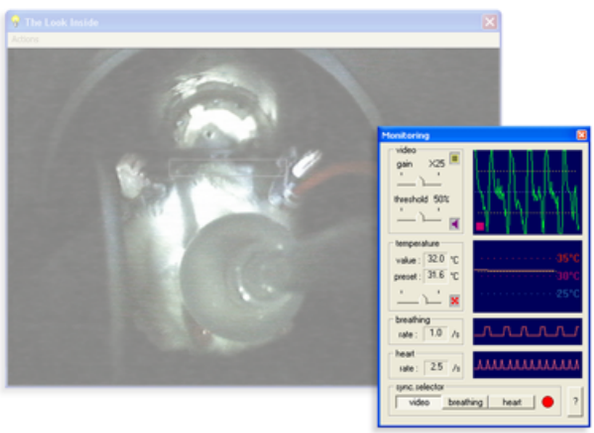




4D TIME-RESOLVED *IN-VIVO* MICRO-CT

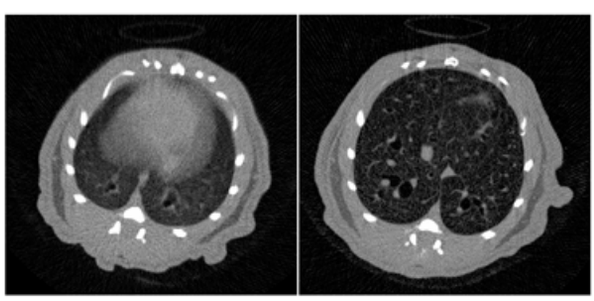
All *in vivo* micro-CT scanners for small animal imaging are supplied with a integrated physiological monitoring subsystem, which allows the operator to see a real-time colour image of the animal during scanning, and to keep the animal in comfortable conditions and temperature. The system provides gating signals for synchronization of scanning to local body movements, respiration activity or heartbeat. It also creates reference timemarks for invented by SkyScan time-resolved reconstruction of heart and lung dynamics. In this 4D scanning mode, multiple projection images taken at each rotation step are sorted post-scan into breathing or heart time bins using recorded physiological monitoring time-marks.

DIRECT MOVEMENT DETECTION



A miniature colour TV-camera is mounted on the animal bed equipped with white LED illumination to produce a real-time image of the animal during the scan. The software analyzes the video stream from a user-selected area of the image, which the operator can position on a part of the animal body where breathing movement is visible. These movements are detected and converted into a movement waveform to provide a monitor of breathing, a gating signal for synchronized scanning and timemarks for time-resolved micro-CT reconstruction. The monitoring also includes temperature stabilization by heated airflow, which maintains the scanned animal at a selected temperature, to prevent cooling of the animal under anaesthesia. Both current and target temperature are displayed on the screen during the scan.

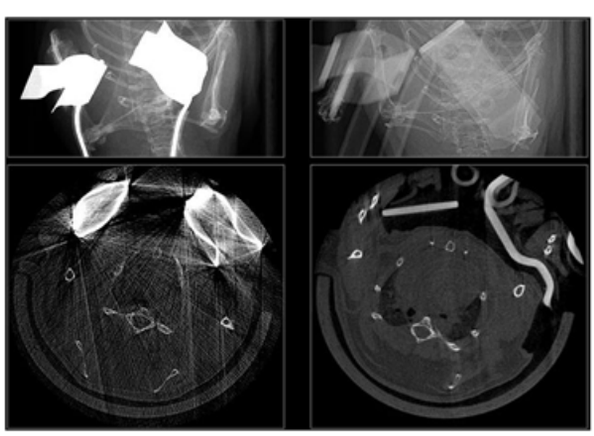
RESPIRATORY GATING



in vivo mouse scans without (left) and with (right) respiratory gating.

The physiological monitoring sub-system includes a face mask and tube linked to an air/gas movement sensor, for direct breathing detection and output of gating signals. These monitoring functions enable a range of options for synchronised scanning to suppress breathing motion or to resolve lung movement dynamics. For optimal control and precision of breathing-gated scanning, a small animal ventilator can be connected which forces the animal's breathing via tracheal intubation, and delivers an electronic pulse for gating.

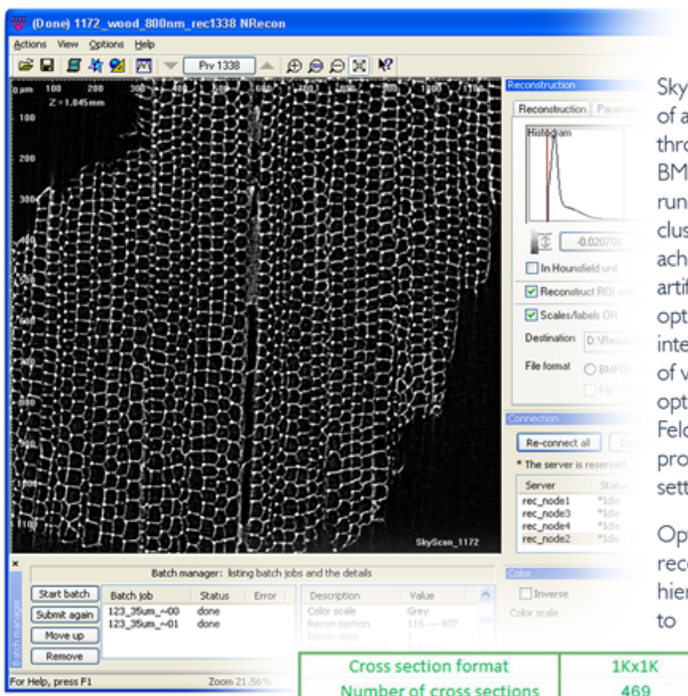
ELECTROCARDIOGRAPHY



Shadow projections (top) and reconstructed slices (bottom) through a mouse body with attached metal electrodes (left) and carbon-based electrodes developed by SkyScan (right).

The electrocardiograph monitoring system consists of a sensitive amplifier and specially developed ECG wiring and electrodes which contain no metal parts. The wires and electrodes employ advanced carbon-fiber conductive parts with X-ray absorption similar to the animal tissues for uncompromised image quality. The ECG system can be used for cardiac scan gating and for investigation of dynamics of the heart by scanning in time-resolved mode.

SkyScan supplies all micro-CT scanners with high-speed volumetric reconstruction software, which can be optionally accelerated by a cluster of several computers connected by a gigabit network. The results of 3D reconstruction can be displayed by slice-by-slice scrolling, by three orthogonal sections through any internal point of the reconstructed space, or by conversion to realistic 3D images by volume rendering program.



VOLUMETRIC RECONSTRUCTION

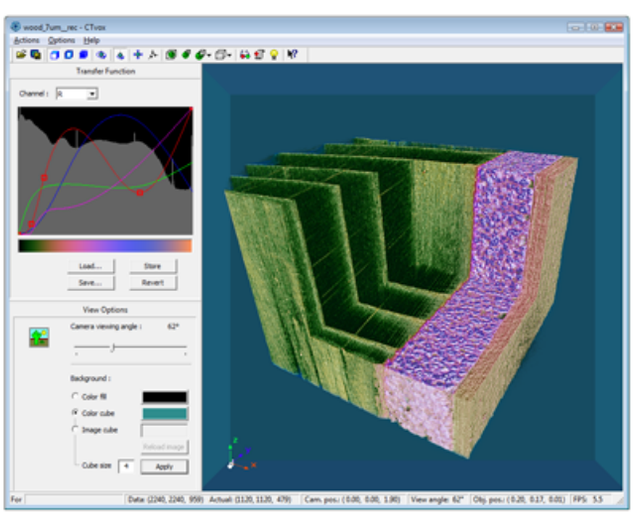
SkyScan's reconstruction software "NRecon" uses the set of acquired angular projections to create a set of virtual slices through the object. Reconstructed slices can be saved in BMP, TIFF, JPG or numerical data format. The program can run on one PC or distribute the reconstruction across a cluster of several networked PCs working in parallel to achieve exceptional speed. Reconstruction includes ring artifact correction, beam-hardening correction, alignment optimization, reconstruction in a restricted volume of interest, reconstruction of objects larger than the field of view, Hounsfield units calibration and many other options.The standard NRecon engine uses a modified Feldkamp reconstruction algorithm. User-friendly batch processing allows many reconstruction jobs with different settings to be run sequentially without operator input.

Optional InstaRecon® reconstruction engine - the fastest reconstruction software in the world - uses a unique hierarchical algorithm, which provides speed-up x10 to >x50 with greater speed-up for larger data sets.

Cross section format	1Kx1K	2Kx2K	4Kx4K	8Kx8K
Number of cross sections	469	938	1878	1668
Number of projections	241	481	961	2037
NRecon/singlePC	6m	1h40m	30h [1day+6h]	218h [9days]
NRecon/cluster 4	1.5m	28m	7.5h	57h [2.5days]
InstaRecon®singlePC (speed-up)	25s (x15)	4m (x25)	32m(x56)	236m [4h](x55)
InstaRecon®cluster 4 (speed-up)		3m (x9)	20m(x22)	116m [<2h](x30)

DATA VIEWER, FORMAT CONVERTER

SkyScan's "Data Viewer" displays reconstructed results as a slice-by-slice movie or as three orthogonal sections, centered at any selected point inside the reconstructed space. One can rotate and resample reconstructed volume in any orientation. Additional features include 4th dimension for time-resolved tomography and compression/tension, variable smoothing, measuring and saving distances and intensity profiles. A format converter utility "TConv" converts between TIFF, BMP and JPEG files with adjustment of colour palette, renaming, resizing and combining of datasets. A utility is also provided for conversion to DICOM 3 format.

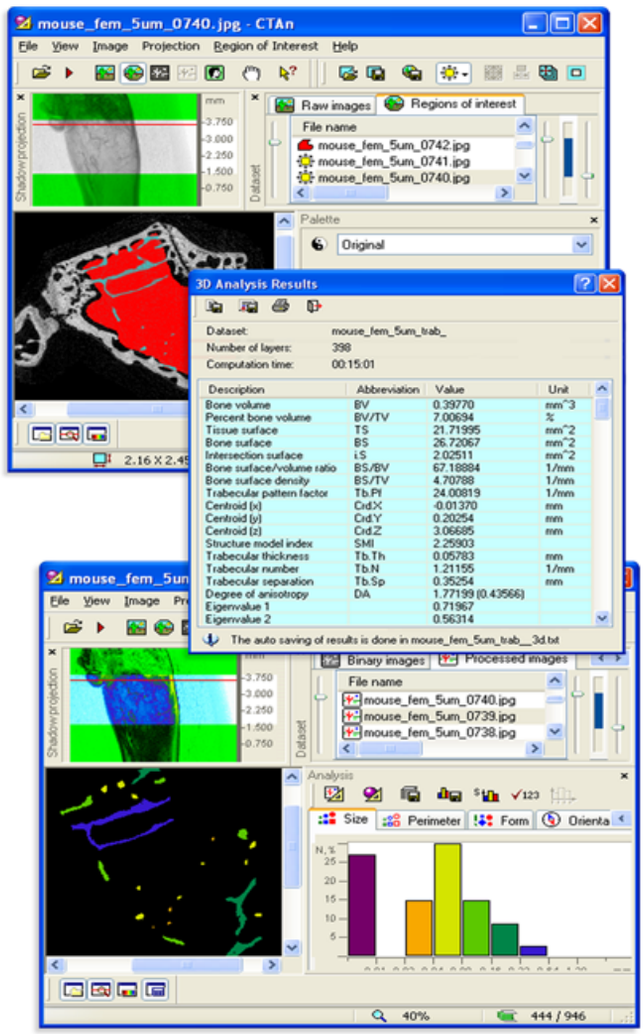


VOLUME RENDERING

SkyScan's volume rendering program "CTvox" displays set of reconstructed slices as a realistic 3D object with intuitive navigation and manipulation of both object and camera, a flexible clipping tool to produce cut-away views, background selection including custom scenery and an interactive transfer function control to adjust colors and transparency. A "flight recorder" function allows fast creation of "fly around" and "fly through" animations based on the selection of several key frames with automatic interpolation in between. Imaging possibilities include lighting, shadows and stereo viewing.

All SkyScan scanners are equipped with a software package for 2D and 3D quantitative analysis of reconstructed volumes, the program "CT-analyser" (CTAn), and software for realistic 3D visualization by surface rendering "CT-volume" (CTVol). These programs can run on the supplied workstation or on any of your laboratory's desktop or notebook computers.

2D / 3D IMAGE ANALYSIS



SkyScan "CT-analyser" allows accurate and detailed study of micro-CT datasets for morphometry and densitometry. Powerful, flexible and programmable image processing tools allow a wide range of segmentation, enhancement and measurement functions for analyses ranging from porosity to contact surface around high-density insertions to complex architectures. Versatile volume of interest selection tools are included.

Main software features are:

- o Import and output of dataset in tiff, bmp, jpg
- o Segmentation by global, multi-level and adaptive methods
- o Advanced region/volume of interest selection tools
- o Measures 3D distances and angles
- o Creates maximum intensity projection (MIP) images
- o Calibrates density as HU, BMD or attenuation
- o Smooth, sharpen, despeckle, morphological operations etc.
- o Programmable stacking of functions ("scripting")
- o Analysis of integrated structures within VOI in 2D, 3D
- o Analysis of all individual objects within VOI in 2D, 3D
- o Parameters measured (including 2D and 3D):
  - o Object (pore, particle, etc.) or "bone" volume
  - o Object or "bone" surface
  - o Structure or "trabecular" thickness
  - o Structure or "trabecular" separation, number
  - o Structure Model Index (SMI)
  - o Fragmentation index or "trabecular pattern factor"
  - o Euler number
  - o Degree of anisotropy (+eigenvalues, eigenvectors)
  - o Fractal dimension (Kolmogorov)
  - o Moments of inertia (x, y, polar, product), eccentricity
  - o Detailed analysis of porosity
- o Automated batch analysis
- o Measurements validated by real and virtual phantoms
- o Creates 3D models by several rendering algorithms
- o Export triangulated 3D models in STL format

SURFACE RENDERING

"CT-volume" (CTVol) uses triangulated models from "CTAn" and provides a virtual 3D viewing environment, flexible and rich in features, to give you a wide range of options for 3D presentation of micro-CT results.

"CT-volume" allows:

- o Movement and rotation of single and multiple objects
- o Selection of background colour including scenery
- o Selection of viewing position and angle
- o Model movements by mouse or using selected steps
- o Control of object texture, colour, lighting and opacity
- o Cut along a selected plane to reveal internal structure
- o Resampling of a dataset in any 3D orientation
- o Stereo viewing using glasses with colour filters
- o Semi-automated creation of animated "movies"
- o Export uncompressed or compressed movies (*.avi)