Application Fields
Material engineering in general
including petroleum, rubber, plastics, resin, polymer, granules (dosage form), methane hydrate, concrete/gravel, fuel cell, carbon nanotube, paper, pulp fiber, ceramic, catalyst, bone, dental/medical material, precision/electronic component, semiconductor.

Input data format
A series of tomographic image obtained through imaging devices such as X-ray CT, CLSM and TEM tomography.

Before conducting 3D image analysis on ExFact Analysis, the image stack needs to be preprocessed, including the extraction of the region of interest, on ExFact VR. ExFact VR supports various file formats including tiff, bmp, dicom and original forms of different devices.

Case Example
Presentations at the 18th Annual Meeting of the Japan Society of Polymer Processing (July, 2007), and the 6th Symposium on Non-destructive Evaluation using Ionizing Radiation

Title: 3D image analysis by X-ray CT for glass fiber within resin cast

When casting resin added with glass fiber, the orientation of the fiber have strong connection with its mechanical properties and casting defects such as warpage. We used an industrial X-ray CT device as a convenient method to observe fiber orientation in a cast plate. The shapes and distribution of the fibers were examined based on three-dimensional images. We used ExFact Analysis to analyze the fiber orientations in the skin and core layers, whose results were then compared to the ones obtained through computer simulations.

Three-dimensional Image Analysis Software

ExFact Analysis Series

MA (Medial Axes)

11um ← fiber width → 55um

Imaging technologies such as X-ray CT, CLSM and TEM tomography provide a series of tomographic image of industrial products and materials for the construction of their 3D images. ExFact Analysis, a software based on the novel concept of “Medial Axes” to capture the complex structure of various objects, offers a tool to conduct statistical evaluation/analysis on the properties of those 3D images, including shapes/distributions of grains/voids, as well as orientations of fibers.
Basic Concepts

Newly Developed Segmentation Process

A cross sectional (tomographic) image obtained with imaging devices, such as X-ray CT, basically consists of pixels of various gray values. Each of these pixels represents the corresponding point of an imaged object, with their gray values corresponding to the material density of the points. On a digital image, whose spatial resolution has a certain limitation, the intensity values of marginal region become lower than their true values (which is called “partial volume effect”). This effect, along with noises and artifacts, makes it difficult to obtain an ideal image in which material phase and pore space are clearly separated.

Equipped with a newly developed segmentation algorithm, ExFact Analysis carries out binarization process based on its three-dimensional scanning of highly-intricate material/void-space structure. The software sets two thresholds (high and low) on a 3D image histogram, where the voxels with gray values higher than the high threshold are classified into material phase, while those with lower values than the low threshold into void space. Those with in-between gray values are classified into either of the two categories after the software statistically processes the gray values of their neighboring voxels, providing more probable contour estimation. The resultant output file after the segmentation can be used on ExFact VR for further image processing.

Medial axis

ExFact Analysis constructs the “Medial Axis” of the object - skeleton of void space represented in a union of one dimensional curves. This lower dimensional representation of the object, while preserving important geometric properties, is easier to analyze than a 3D image. ExFact Analysis uses the medial axis as the basis for understanding the complicated 3D properties of the original object.

Preparations for quantitative analysis

First, fibers are divided where they contact, intersect or diverge, into individual paths. These points are defined as “clusters,” shown in blue in the figures on the right. The angles that the smallest of the angles made by two crossing fibers.

A crossing angle is defined as the smallest of the angles made by two crossing fibers. Bonds are defined as the points at which a fiber contact other fibers.

Flow Steps

Objects of analysis

Fibrous materials such as fibers, fuel cells and wires.

Loading image data, extracting the region of interest, and converting the file to a format readable on ExFact Analysis.

Conducting binarization on a 3D volume data, separating material phase and void space, and proceeding with analysis process.

3D visualization of the medial axis processed by ExFact Analysis.

ExFact Analysis calculates various statistical values for material evaluation.

Graphs Plotted Based on Analysis Results

Distribution of number of bonds on individual fibers

The three principal axes of moments for fibers are calculated normal to unit length and plotted on a system.

Distribution of crossing angles between fibers

A crossing angle is defined as the smallest of the angles made by two crossing fibers.

Fiber length Distribution

Cluster: a point that joins paths on the shortest path, where the length of the fiber is defined by the distance between the two centers.

Tortuosity

Visualization of all fiber orientation by colored mesh.

Each colored vector is composed of all fibers connecting to a cluster only at one end.

Cluster: a point that joins paths on the shortest path, where the length of the fiber is defined by the distance between the two centers.

Tortuosity is calculated for different types of fibers (all, LL, BB and BL).

Bonds are defined as the points at which a fiber contact other fibers.

Shortest path distribution

ExFact Analysis® VR for further image processing.

ExFact Analysis uses the medial axis as the basis for understanding the complicated 3D properties of the original object.