

**DEFINIENS**<sup>®</sup>  
Understanding Images

DEEPER INSIGHTS  
FASTER RESULTS  
BETTER DECISIONS

# Definiens Cognition Network Technology<sup>®</sup>



# The Image Analysis Challenge

From studying distant galaxies to probing minute biological structures, we rely on images to understand the environment. But interpreting images is an immensely complex and challenging task.

The human mind has a remarkable ability to make sense of images, identifying objects and extracting insights. It handles ambiguous or partial information by making inferences based on the image as a whole, the relationship between objects, and external and contextual information.

Scientists, radiologists, pathologists, remote sensing analysts and other experts hone their image analysis skills over years. They intuitively apply their knowledge and experience when interpreting images enabling them to make acute judgments in ambiguous cases.

It is not surprising that computers have found the challenge of image analysis almost impossible to solve. But as the number of images in science and industry grows exponentially, the need for automated image analysis is more urgent than ever.

## Automated image analysis

Attempts to automate image analysis have been ongoing for decades. But despite increases in computational power and imaging capabilities, fundamental advances in automated image analysis have been limited.

The heart of the problem is that computers examine images pixel-by-pixel. By contrast, human beings intuitively aggregate pixels into 'objects' and understand the context and relationships between those objects. This is how we make sense of images and draw intelligent inferences from them.

But how can a computer duplicate the complex and subtle processes of the human mind?

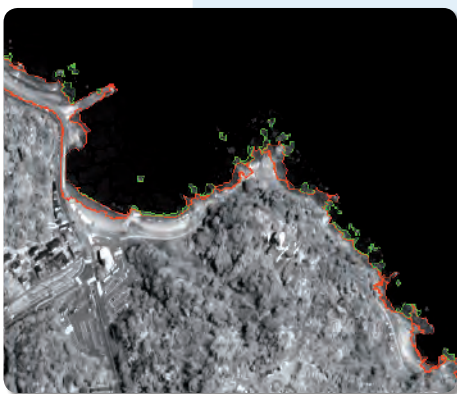


Figure 1 Generalization of coast line: classification elements that are too small are eliminated



Figure 2 Classification result containing buildings, impervious surfaces, water and non impervious surfaces.



Figure 3 Analysis result of a CT scan

# Definiens Cognition Network Technology®

Definiens Cognition Network Technology® has been developed by Gerd Binnig, the 1986 Nobel Laureate for Physics, and his team. It emulates the complex human cognitive processes involved in image analysis to extract information – from microscope to satellite images.

In conventional automated image analysis, 'objects of interest' are identified using a series of pixel-based filters. These filters, such as intensity thresholds and gradients, compare pixels to their neighbors. The goal is to transform the original image so that the areas of interest can be extracted by simple threshold measures.

In developing Definiens Cognition Network Technology®, Gerd Binnig and his team made a radical departure from this pixel-based approach.

Definiens Cognition Network Technology® does not simply identify the 'objects of interest' but all of the intermediate objects together with their interrelationships (context). So for example, in extracting nuclei from a tissue slide, Definiens Cognition Network Technology® identifies the cells, cell membranes, cytoplasm along with the nuclei.

In effect, a model is built which is represented by Definiens' unique Cognition Network. This stores all of the objects, sub-objects and their semantic relationships in a clear hierarchy.

The difference in approach is profound. It is the contextual information contained in the Cognition Network that enables the automated extraction of information – in exactly the same way as a human being makes sense of the image.

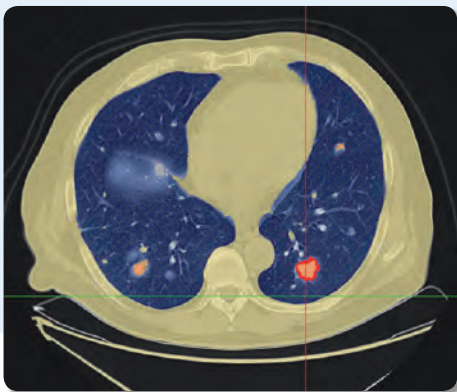


Figure 4 Semi-automated analysis of lung tumor based on CT data

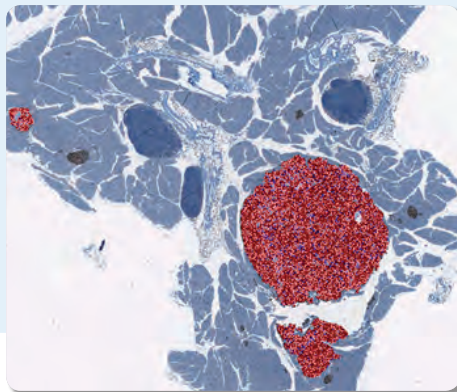


Figure 5 Annotation of pancreatic tumor in whole slide tissue scan

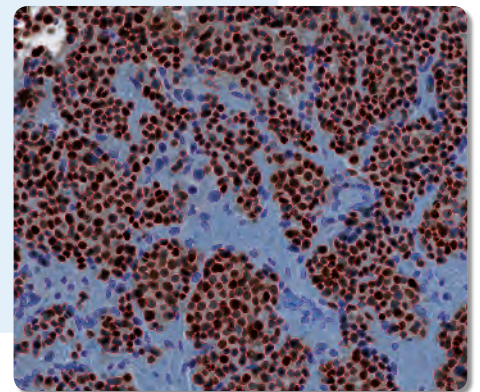


Figure 6 Detailed classification result of nuclear biomarker

The easiest way to understand how context-based Definiens Cognition Network Technology® works is through a simple example.

Question: What is this?



Answer 1: Two circles



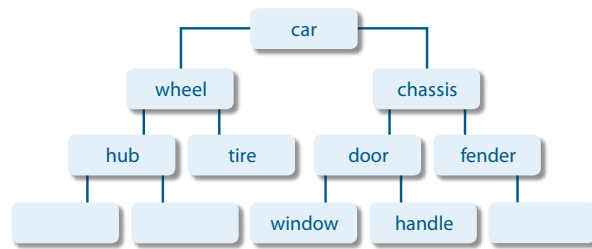
Answer 2: A car

With the addition of a chassis, the circles are immediately identified as wheels. The circles have not changed, but the human mind uses context and relationships with other objects to make intelligent inferences. This, in essence, is how Definiens Cognition Network Technology® works.

Image



Cognition Network



The concept that underpins Definiens technology is that the semantic information necessary to interpret images must be understood as objects, not individual pixels. With Definiens, an understanding of these objects and their mutual relationships and properties is captured in a hierarchical structure (the Cognition Network). Using the Cognition Network, objects within images can be identified by their appearance, their context and their relationships to each other.

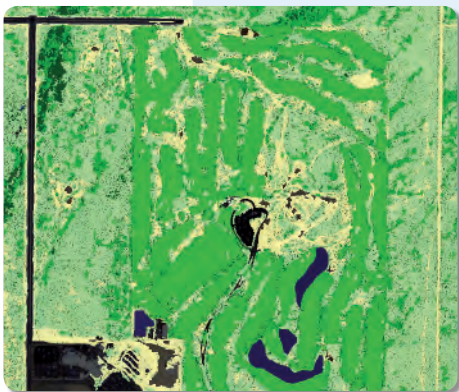


Figure 7 Monitoring of land cover to measure the influence of a golf course on shrubs

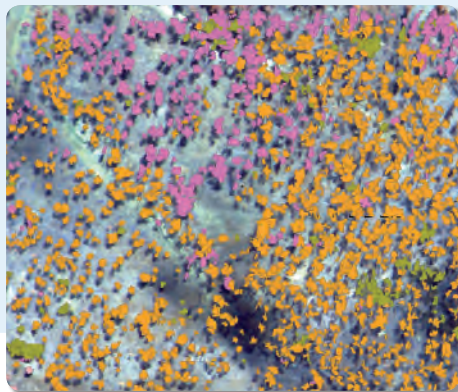


Figure 8 Tree crown delineation and species classification based on CASI data

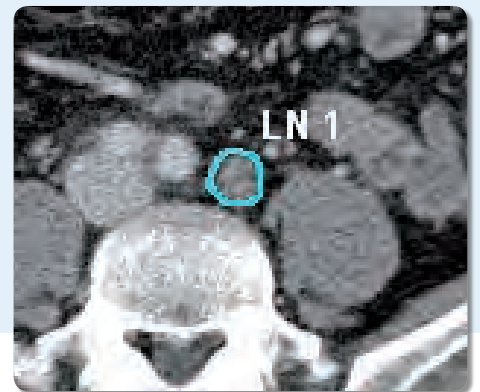


Figure 9 Semi-automated segmentation of lymph nodes in cancer patient

The process of identifying and analyzing objects using Definiens Cognition Network Technology® is iterative. As some objects within an image are identified, so it becomes easier to identify others. (Once you have identified a car, it is far easier to recognize that a metallic object on its side is a door handle.)

Definiens describes the image analysis process using a high level script (Cognition Network Language) which is developed in a graphical environment and ensures rapid prototyping as well as the iterative development of applications. While identifying and measuring objects of interest users can test, refine and fine tune analyses at any point in the workflow. This approach not only dramatically reduces the time to see results, it makes it easier and more intuitive to create and validate new applications that explore fresh avenues of enquiry.

Definiens allows users to easily identify objects of interest and to automate image analysis tasks with a high degree of accuracy. And since the technology works for all modalities, images from different sources can be compared enabling maximum insight to be extracted from image data.

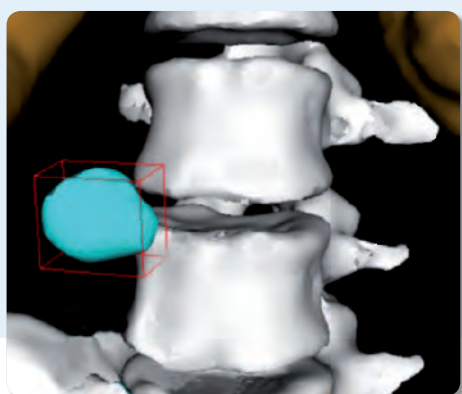


Figure 10 3D rendering of lymph node classification result

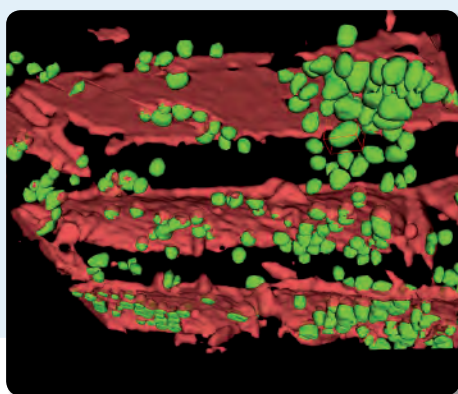


Figure 11 4D time series of aquatic plant tissue (Elodea Canadensis)

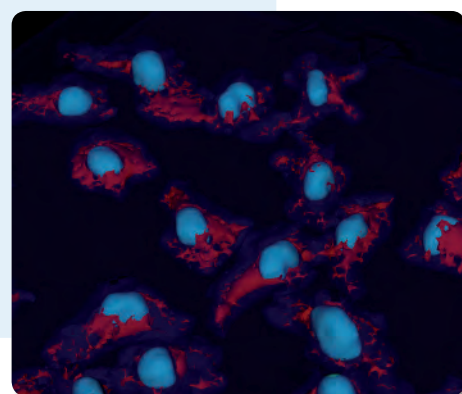


Figure 12 Classification result of confocal image of endothelial cells

# Definiens Cognition Network Technology<sup>®</sup> in Action

## Geospatial Analysis Example: Identifying rivers and lakes from a satellite image

Figure 13a shows a satellite image of an area of land. It is a trivial exercise for a person to identify the river and lakes but for a computer the task is surprisingly difficult.

Definiens' technology identifies water by searching for blue pixels (figure 13b). However, not all blue pixels indicate water – there may be individual blue pixels in the middle of a field. So Definiens aggregates blue pixels into clusters and identifies as bodies of water only those clusters that are sufficiently large (figure 13c).

To separate the rivers from lakes demands a different segmentation process. It requires the understanding that rivers are long and thin while lakes are generally round. By translating these insights into a set of rules, Definiens' technology can distinguish rivers from lakes (figure 13d).

Finally, Definiens' technology can measure the size of the water bodies and compare the results to images of the same region at a previous time, accurately quantifying any changes.



Figure 13a RGB aerial photo



Figure 13b Segmentation result



Figure 13c Object-based classification of waterbodies



Figure 13d Separation of rivers and lakes by leveraging shape criteria

## Life Sciences Example: Identifying cell types within skin tissue

Definiens' technology can identify and count different cell types in a whole tissue slide scan (figure 14a).

With hematoxylin and eosin staining, a nucleus always appears blue while cytoplasm appears red. The challenge is to distinguish between different nuclei of similar size and shape and between cytoplasm and connective fibers of similar color.

Definiens' technology first distinguishes between tissue and background by using their different spectral properties (figure 14b). At a higher magnification, cells are identified by using the simple definition "objects that contain both red cytoplasm and blue nuclei", whereas connective fibers can be seen as "red elongated objects without nucleus objects" (figure 14c). Nuclei are then identified as round blue objects and their surrounding red area as cytoplasm (figure 14d). Within the heterogeneously stained nuclei, Definiens identifies blue regions as DNA and red stained regions as nucleoplasm (figure 14e).

Finally, returning to a larger scale (figure 14a), a dense accumulation of nuclei or cells suggests a tumor or inflammation whereas loosely distributed cells represent the healthy condition.

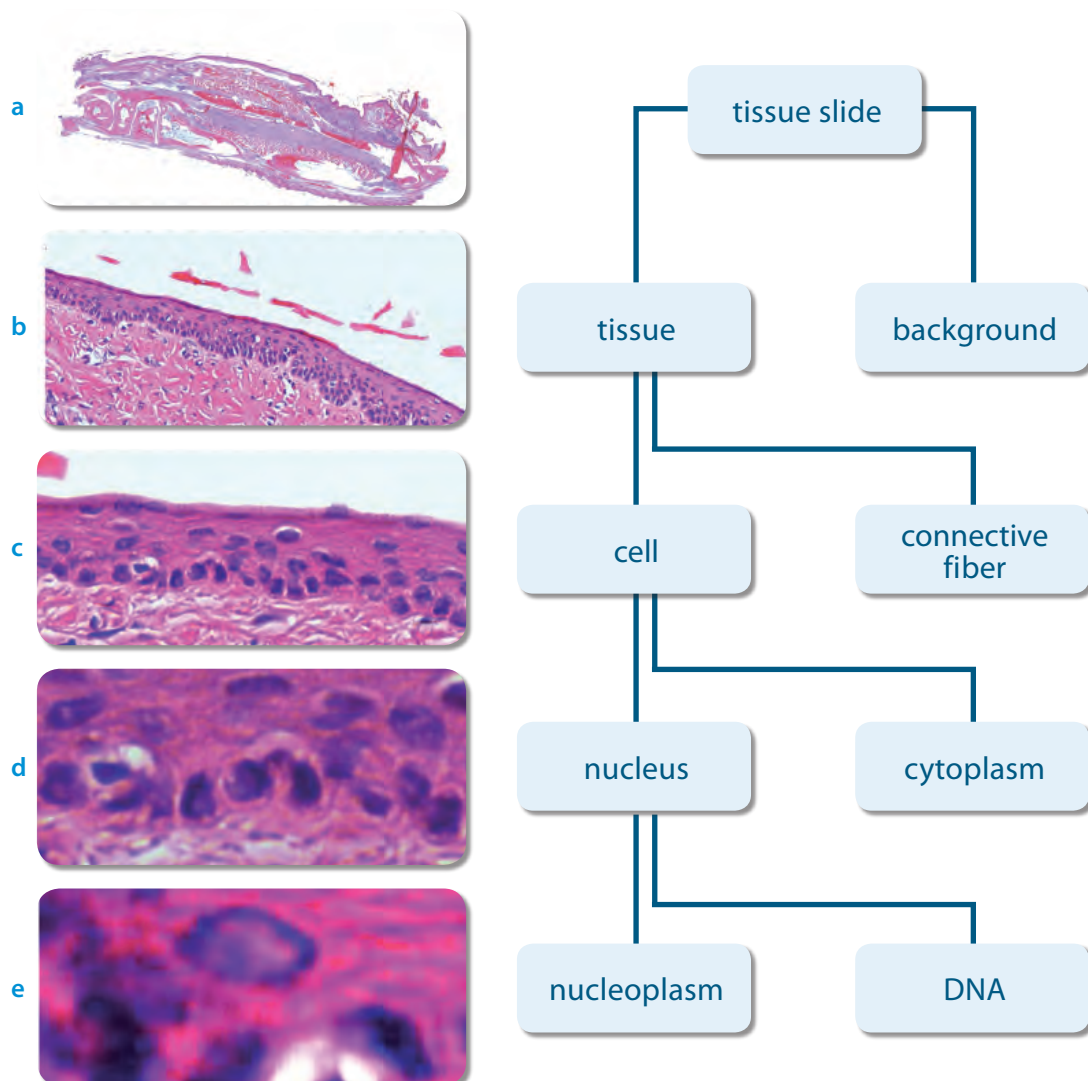


Figure 14a – e H & E stain of thin section of a mouse foot at different magnifications.

## Medical Imaging Example: Identification and quantification of organs within a CT scan

Figure 15a: In DICOM CT (Computer Tomography) images, the intensity is normalized to Hounsfield units (HU), a standard scale for matching the attenuation of x-rays to specific tissue types. Definiens' technology can present the CT images in 2D Multiple Planar Projection (MPR) and advanced 3D object rendering.

Definiens Cognition Network Technology® first creates object primitives – in this example by separating air from non-air objects. Using relational context information, the technology differentiates between air within the body and air outside the body (background) and uses size criteria to separate the body from its environment.

Figure 15b: To identify the aorta, the segmentation and classification of structures are further refined. Hounsfield units are used to identify bone and blood vessel candidates within the body objects. Using a fuzzy class description that takes into consideration size and shape constraints, the aorta descending is identified among other blood vessel candidates within a defined region of interest in the human body.

Figure 15c: The classified aorta descending then serves as a context object to identify the long blood vessel candidate which is located above the aortic arch. The aorta ascending is identified in a similar way among other blood vessel candidates, located below the aortic arch.

Since the aorta ascending leads directly into the heart it can be used as an ideal context object for further segmentation, analysis and quantification of the heart.

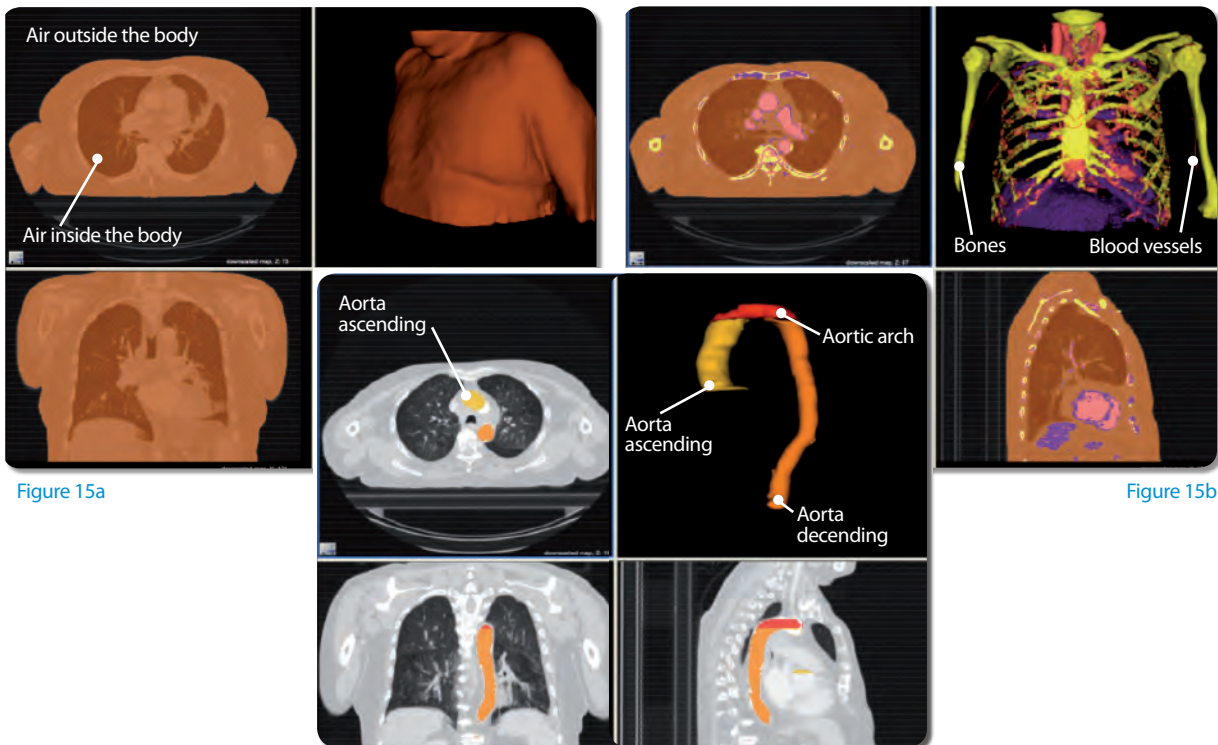


Figure 15c

Images: PD Dr. Dr. Loose Klinikum Nuernberg Nord

# The Value of Definiens Cognition Network Technology®

Definiens Cognition Network Technology® is at the heart of all Definiens software products, from the most advanced 4D image analysis to simple 2D analysis using pre-defined rulesets.

Definiens' technology is ideal for any organization that wants to automate the extraction of data and insight from images. Since Definiens can be used with all image modalities at any level of magnification, it is uniquely suited to Translational Science and Geo Intelligence Systems.

Definiens offers organizations an automated image analysis solution of immense flexibility and power.

## Automatic capture of knowledge

Definiens Cognition Network Technology® transforms the knowledge and experience of domain experts into rule sets that a computer can follow. By automating these routines, Definiens' technology can process thousands of images in a fraction of the time that it would take experts.

## Accurate results

Applications based on Definiens' technology are extremely accurate in measuring and quantifying objects, for example, calculating the sizes of individual trees in a forest, counting the number of stained cells on a tissue slide or monitoring objects such as lymph nodes that differ in size, shape and location in a human body.

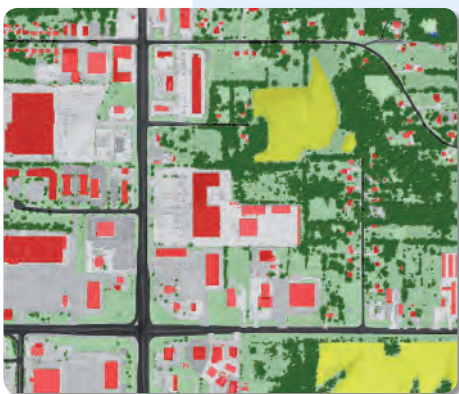


Figure 16 Extracted tree canopies from LiDAR data

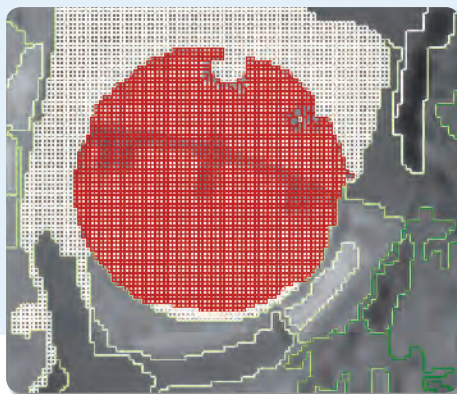


Figure 17 Gas tank: If color information is not sufficient, context information can be used

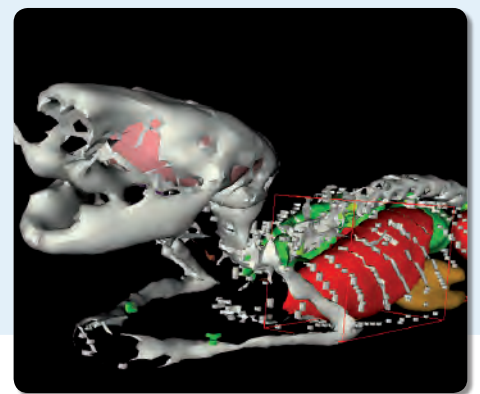


Figure 18 Anatomical model of murine CT/SPECT data

## 2D, 3D & 4D

Definiens Cognition Network Technology® can perform 2D, 3D and 4D image analysis tasks. It can make accurate volumetric measurements over time, for example, assessing the change in volume of a tumor and thereby providing a precise evaluation of its growth or decline.

## Consistent results

Definiens Cognition Network Technology® provides consistent results, eliminating the variability in the judgments of individual experts and the even greater variation between different experts.

## All image modalities

Definiens Cognition Network Technology® works with images of different magnifications, resolution and modalities including electron microscopy, optical microscopy, confocal microscopy, radiology, magnetic resonance imaging (MRI), conventional photography, SAR, Lidar, pan-chromatic, multispectral and hyperspectral sensors.

## Intuitive to use

Definiens Cognition Network Technology® features an intuitive graphic user interface designed for subject matter experts and other end users. This makes it easy to adapt off-the-shelf image analysis applications while more experienced users can use the advanced tools to develop new applications from the ground up.

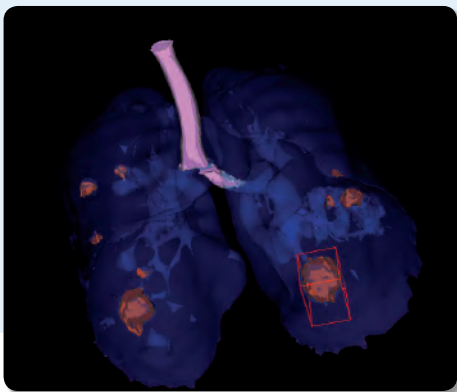


Figure 19 3D rendering of lung tumor annotation

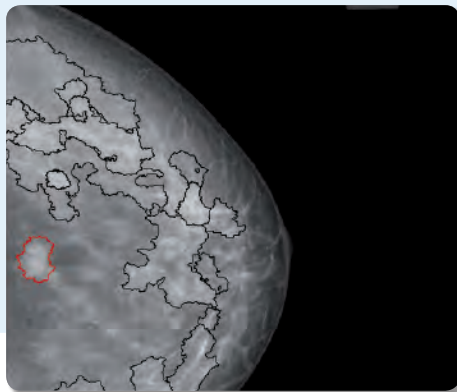


Figure 20 Segmentation result of mammographic image

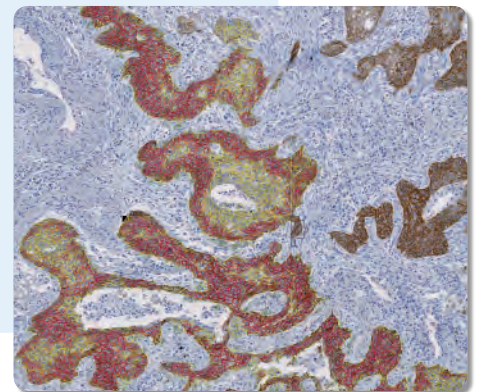


Figure 21 Cell membrane detection in colon cancer biopsy

# The Definiens Edge

Definiens Cognition Network Technology® surpasses every other automated image analysis system today across nine different criteria delivering deeper insights, faster results and better decisions.

## Deeper Insights

**Definiens handles complex real world situations.**

The multi-scale object network can explore an image, the objects in it and the relations between them simultaneously on multiple levels. The technology can even be used to detect anomalies like cars queuing up in front of a building or abnormal cells in a tumor.

**Definiens supports all common types of imaging systems.**

Definiens' technology interprets all types and combinations of digital image data. In the geospatial intelligence arena this covers spaceborne and airborne sensors including panchromatic, multispectral and hyperspectral optical images, infrared, LIDAR, single channel, multifrequency and multipolarimetric SAR. In life sciences, it includes all the major automated microscopes, digital slide scanners and noninvasive imaging scanners.

**Definiens provides detailed quantification of images.**

Definiens' powerful data structures allow extraction of the relevant data at the right time without the need for complex and time consuming post processing. The extraction can be fully automated.

## Faster Results

**Definiens' applications can be developed in a fast and modular way.**

Applications can be developed rapidly by combining existing ruleware modules. Complex tasks can be addressed with the full power of Definiens Cognition Network Technology®, which in turn creates ruleware that can easily be reused in other situations.

**Definiens applications identify the most important images and the areas of interest within them.**

Definiens' applications identify the most important images and the relevant objects and structures within them even under difficult circumstances and in difficult cases. The technology is massively scaleable and is capable of automatically processing large, high resolution images.

**Definiens enables scientists and analysts to extract information rapidly.**

User-friendly interfaces assist scientists, analysts and informaticians to extract information in fully automated and semi-automated modes.

## Better Decisions

**Definiens provides reliable information for decision making.**

The deterministic approach of Definiens Cognition Network Technology® ensures that all results are fully reproducible and the method used to create them is transparent. The results of the analysis can be presented in the format best suited for the decision making process: as an object saved in a database, documented in an object-based html report or summarized in a statistical presentation.

**Definiens integrates image intelligence across existing processes.**

Definiens' technology integrates easily into any environment. As a result, it supports end-to-end intelligence processes across the entire enterprise. In life sciences, this facilitates translational medicine. In earth sciences, it maximizes the combined value of intelligence from all sources as it integrates automatic image analysis into the overall GIS workflow.

**Definiens will continue to lead the field.**

The unique patented software, built on an open standards-based architecture, represents a new paradigm in automated image analysis. Gerd Binnig and his team continue to lead the research and development at Definiens, ensuring that the technology will remain at the forefront of Enterprise Image Intelligence®.

# DEFINIENS<sup>®</sup>

Understanding Images

DEEPER INSIGHTS  
FASTER RESULTS  
BETTER DECISIONS

Definiens is the number one Enterprise Image Intelligence<sup>®</sup> company for analyzing and interpreting images on every scale, from microscopic cell structures to satellite images.

The patented Definiens Cognition Network Technology<sup>®</sup>, developed by Nobel Laureate Prof. Gerd Binnig and his team, emulates human cognitive processes of perception to extract intelligence from images. If you are interested in learning more about how Definiens could address the challenges you face, please visit our website.

[www.definiens.com](http://www.definiens.com)

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