OLYMPUS
Your Vision, Our Future

Quantitative image analysis

Revealing hidden information in digital images

Abstract:

Quantitative information is of great importance within manufacturing and quality control, bringing objectivity and confidence to the decision-making process. Under the correct conditions, an image acquired with light microscopy will contain a wealth of information, but the trick is how to extract and utilise this effectively. As digital imaging technologies evolve, micro-imaging software addresses this challenge, incorporating a range of advanced capabilities to reveal the most insightful and relevant information for each task.

Light microscopy is a popular tool within manufacturing and quality control workflows. However, at first glance, the images generated appear purely qualitative, and the human eye can be extremely subjective – especially when distinguishing colours. This information must therefore be transformed into numerical information, enabling the objective quantitative analysis necessary for reliable decision-making.

Through the use of digital imaging systems within light microscopy, this can now be achieved from computational analysis, with the latest software facilitating the extraction of data from digital images and therefore enhancing our understanding of matter.

With software-based analysis of digital images being fast, efficient and avoiding operator error, this approach is becoming increasingly popular, streamlining tasks such as phase analysis, porosity analysis and particle distribution. Dedicated materials science software is optimised for exactly this purpose, with a modular design allowing the platform to be adapted for each application, while adhering to the latest quality standards. Software functions play a vital role throughout the complete workflow, and this begins with the information that is first captured within the image.

Quantitative Image Analysis at a Glance

- The role of numerical data in robust decision-making
- The latest approaches to computational analysis
- Capturing sufficient information while minimising file size
- Effectively utilising thresholding to extract information
- Enhancing analysis for real-world applications with modern software

Key words

- Quantitative image analysis
- Micro-imaging software
- Quality assurance
- Phase analysis
- Porosity evaluation
- Particle measurement

Software Solutions for Materials Science: Olympus Stream

- A comprehensive platform for materials science micro-imaging
- Diverse measurement tools adhere to latest quality standards
- Easily optimised with specialised modules
- Advanced image acquisition and refinement techniques
- Efficient data management and report creation

Information captured within images

Capturing the correct type and amount of information within the image is crucial for insightful analysis, and this depends on optimised image acquisition settings. For example, it is important to use the correct exposure and check the image for clipping – where due to the limits in the dynamic range of the camera, pixel values can become underexposed or saturated, effectively losing their quantitative information. But what do we mean by pixels? Enabling the capture of spatial information, pixels are the elemental components of the digital image, with each containing a wealth of information to facilitate analysis. For example, Figure 1 shows the surface of an antique knife corroded over time, providing insight into several properties, including colour, height and saturation.

Colour can provide much information on a sample. However, storing colour within an image does result in a larger file size, and since detailed colour may sometimes be unnecessary for quantitative analysis, a smaller file may be a higher priority. For this reason, a range of different colour formats are available (Figure 2), with the simplest format being the binary image. Containing just two possible colour values per pixel (black or white), such monochrome images produce a smaller file, while features (e.g. based on height) can also be distinguished with pseudo-colours to facilitate analysis (Figure 2C). However, this type of palette image does incur limitations. Unable to distinguish more than two distinct values, it is not possible to inspect a material composed of three or more phases, such as an alloy. Complex monochrome images encoding a range of light intensities visualised in greyscale instead enable this type of analysis, and therefore present a compromise between the size burden of colour images and the restrictions of the binary format.

Storing true-colour information is achieved through the use of colour spaces, providing a more detailed analysis for many samples. While the RGB (red, green, blue) colour space is formed from intensity levels of the red, green and blue channels, the HSV (hue, saturation, value) colour space instead considers the colour tone, intensity and brightness – in this way being more similar to how the human eye perceives colour.

It is therefore the case that a compromise must be made between file size and the level of information stored within an image, and the quantity of colour values stored within each channel is defined by what is known as bit depth. For example, containing only two possible values per pixel, a binary image carries only one bit; while a 24-bit RGB colour image carries 256 colours per 8-bit channel (red + green + blue). As the bit depth rises, a greater level of colour information is stored at the cost of data storage space.

Revealing hidden information

The information stored within each pixel is only of worth if it is effectively utilised, and this is where value thresholds come into play. By setting limits (either automatically or manually) on properties such as light intensity, a range of relevant pixels can be selected. For example, thresholds may be defined to select only those pixels lying within a specific colour space:

- RGB [r_{min}, r_{max}], [g_{min}, g_{max}], [b_{min}, b_{max}]
- HSV [h_{min}, h_{max}], [s_{min}, s_{max}], [v_{min}, v_{max}]

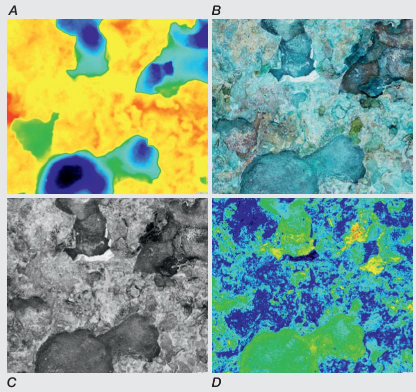

Figure 1: Information stored within images. *When inspecting the roughness of an antique knife edge resulting from surface oxidation, each pixel of the digital image stores different types of information, depending on how it was captured. A) Colour information B) Height map; C) Colour intensity of red; D) Saturation.*

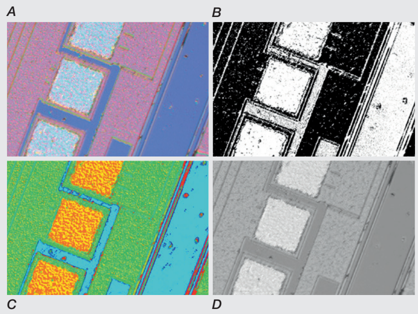

Figure 2: Colour information stored within digital images. *Full colour can be captured for enhanced analysis (A), or images can contain limited colour information to retain a small file size. The simplest format is the binary image, containing only two values: black and white (B), which can also be visualised with pseudo-colours to form a palette image, highlighting a different set of features (C). A compromise between binary and true colour images, monochrome greyscale images store the level of light intensity (D).*

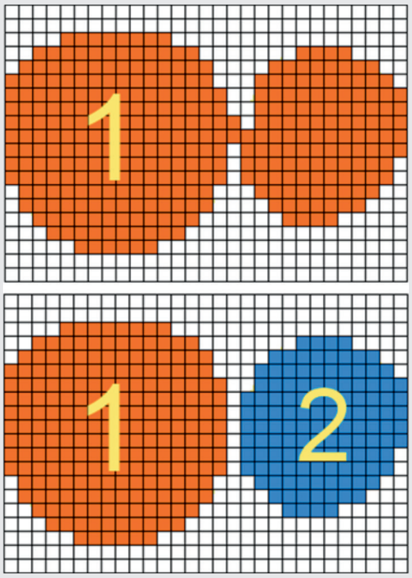

Figure 3: Particle connectivity is determined by neighbouring pixels. *Depending on user-defined software settings linking or separating diagonally neighbouring pixels, two areas may be interpreted as one or two particles (A and B, respectively).*

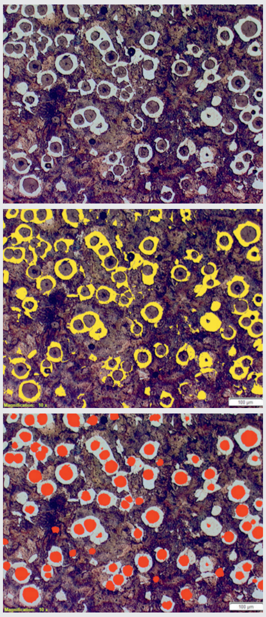

Figure 4: Quantitative phase analysis in cast iron. *Using Olympus Stream image analysis software to assess the casting process of iron, following etching the ratio of ferrite (yellow) and Graphite (red) phases are measured against the dark graphite background.*

This selection process is known as segmentation, and can be achieved even on a binary image by making a mask to retain information from the original image, whilst also retaining a small file size. Pixels linked following segmentation form particles (or objects), and this raises another important factor – particle connectivity. Depending on user-defined settings, neighbouring pixels can be interpreted as being linked or separated, and therefore in some cases this can dictate whether an area of pixels forms one or multiple particles (Figure 3), impacting subsequent analysis. Modern software allows analysis and measurement based on a myriad of different properties, from area and perimeter, through to more specific parameters such as centre of gravity or colour density. However, it is often insufficient to measure just one parameter, and combining several analysis tools instead allows the user to interpret information on multiple properties. Particles can even be filtered out if they fall outside a specified range, for example it should be noted that areas below 30 pixels should be discounted, since anything less is not likely to be significant for many tasks. In addition to thresholding and segmentation, information extracted from a user-defined region of interest (ROI) is useful when features are relevant in a certain area of the sample.

The flexibility of selecting measurement regions and parameters is an incredibly powerful capability of modern software. By picking and choosing exactly which type of information is to be analysed within the image, the user is therefore able to decide which information is revealed to provide insight into the nature of each sample.

Quantitative image analysis in manufacturing

Quantitative information has many uses throughout the manufacturing industry. Inspecting the proportion of the three phases forming cast iron, for example, is important to assess its quality during the casting process. Differentiating the black graphite from the bright ferrite and pearlite phases is a necessary background parameter, and possible under the microscope within an un-etched sample. In order to accurately quantify the ratio of ferrite to pearlite, the pearlite will become dark on etching, allowing the two phases to be distinguished. With digital imaging technology, these phases are accurately quantified using thresholds based on light intensity levels (Figure 4).

Porosity is another characteristic that must often be accurately inspected, since voids indicate the density of a material. Voids that are too large or too numerous can indicate an unacceptable level of weakness in the material, increasing the likelihood of failure in the future. Determining the percentage of porosity present within materials is achieved through calculating the fraction of pores (Figure 5), which can be chosen or classified based on size ranges, and can also be extracted from a defined ROI.

Instead of quantifying the total particulate area (often ignoring smaller particles), the distribution of particles can be classified based on different parameters within the digital image (Figure 6). This task is commonly employed when inspecting filters, for example – essential when analysing the cleanliness of high-precision components such as engine blocks. Through detecting, visualising, identifying and reporting residual particles found on filter media, automotive and aerospace engineers are able to quantify contamination that in turn affects the performance, lifetime and reliability of the final product. In this way, microscope-based residue analysis helps determine the size of particulate contamination down to the micrometre level, measured and classified in compliance with relevant standards.

Facilitating quantitative analysis with modern software

With such a diverse range of tasks, the materials science micro-imaging software must be both comprehensive and flexible, whilst adhering to international standards for quality control. Today's micro-imaging software for materials science draws from the latest developments in digital technology to enhance the quantitative image analysis workflow throughout a range of industrial sectors. As a single, comprehensive software solution for manufacturing and quality assurance, Olympus Stream integrates a diverse array of tasks, from image acquisition and analysis, through to reporting and data management. Moreover, many industrial tasks now demand their own unique quality standards. Designed specifically for industrial applications, Olympus Stream directly incorporates the latest standards into the relevant tools, ensuring validity for acquired data.

Different manufacturing sectors and even organisations implement highly specialised applications, demanding highly specialised quantitative analysis capabilities. Perhaps the ratio of different particle size classifications may be relevant, or only larger particles are significant. With the Olympus Stream software, measuring every kind of particle characteristic is possible, which can be interpreted and reported as best suits each specific application. This level of specialisation is where a modular approach to software design is beneficial, allowing the user to build their own software system to suit individual requirements. Module options, or 'Solutions', can be added to the basic Stream platform, and include dedicated solutions for Cast Iron analysis, Porosity and Particle Distribution, amongst others. This approach to software design guides the user through their specified protocol with improved efficiency. Allowing them to reach desired tools and functions faster in turn provides a much faster route to the end goal in many quantitative analysis tasks - the decision of whether a sample has passed or failed.

Since a variety of information can contribute to how a decision is reached, creating informative reports requires a high level of customisation. Reporting in a clear and accurate manner, whilst adhering to the company's in-house style and format is also achieved through the Stream software. All relevant information from the image analysis process can be included, and the function includes full Microsoft Office integration.

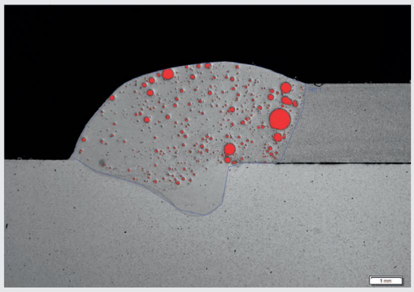

Figure 5: Measuring material density with porosity. *An important characteristic in quality assurance, the complete fraction of pores are visualised as red regions, calculated using thresholds with Olympus Stream software.*

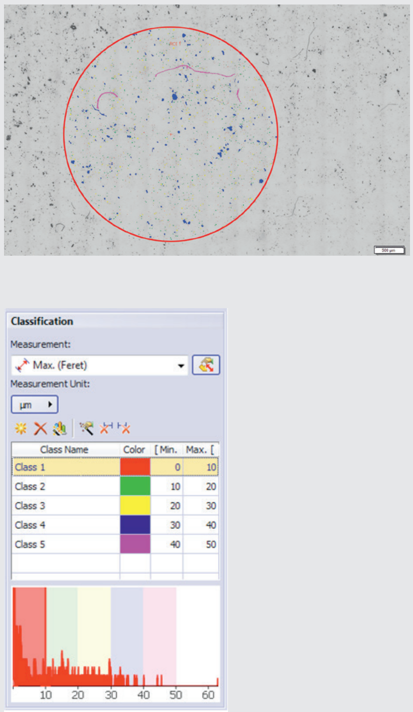

Figure 6: Measuring particle distribution. *A variety of parameters can be measured to reveal different types of information, for example on the distribution of particles in pre-defined classes, here using Olympus Stream software.*

Summary

Quantitative image analysis is crucial within manufacturing and quality assurance, removing the subjectivity and error that arises when an image is assessed with the human eye, instead replacing this with objectivity and confidence. By combining the materials science microscope with the latest micro-imaging software, a single microscope system can be used to perform a range of complex quantitative image analysis tasks throughout many sectors.

Generating quantitative information depends on four main steps: image acquisition, thresholding, segmentation and analysis, and software-based image analysis with Olympus Stream offers many advantages at every stage of the process. Once relevant areas are defined from the digital image, these can be measured and analysed based on a range of different parameters selected by the user, allowing them to extract the most relevant information. Detailed inspection and quantitative image analysis tasks can be performed quickly and precisely, with minimal microscopy knowledge.

Olympus Stream can also be adapted for different measurement tasks, with dedicated software modules available for cast iron analysis, porosity and particle distribution. Optimised for each application, such tools quickly lead the user to quantitative and insightful results, whatever their sample.

Please contact

Ralf Schäfer
(Marketing Communications Manager
Microscopy)
Olympus Europa Holding GmbH
Hamburg, GER
T: +49 (0) 40 23773 5913
F: +49 (0) 40 23773 505 913
E: microscopy@olympus-europa.com
Web: www.microscopy.olympus.eu