Is a Magnification of 20,000 Times Really Useful With Digital Microscopy?

Introduction

Digital microscopes have only a camera for image observation and no eyepieces. Microscopes with eyepieces for visual observation, such as stereo microscopes, can also be equipped with digital cameras. Both types of microscope are used for a variety of technical applications in many different fields and industries.

To evaluate the performance of an optical microscope, knowing its highest achievable magnification is important. For digital microscopy, very high magnification values, such as 20,000x, are sometimes mentioned. This report provides some helpful guidelines concerning the useful range of magnification for digital microscopy.

Magnification defined

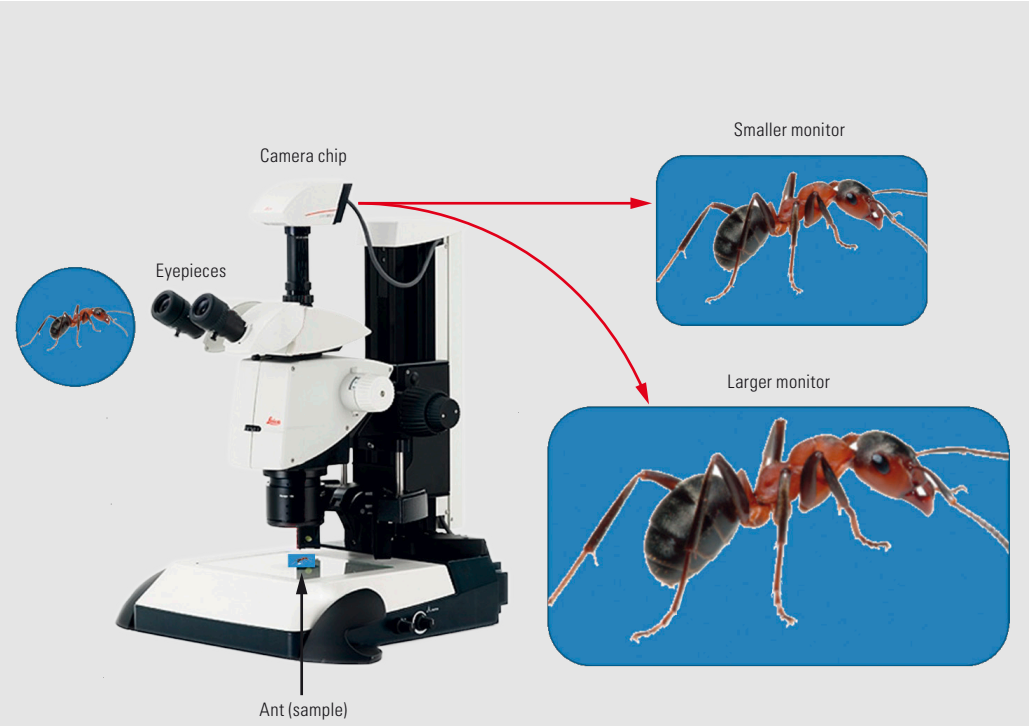
Magnification is defined as the ratio of the size of a feature on an object as seen in an image to the actual size of the feature itself. The lateral, two-dimensional magnification can be determined from:

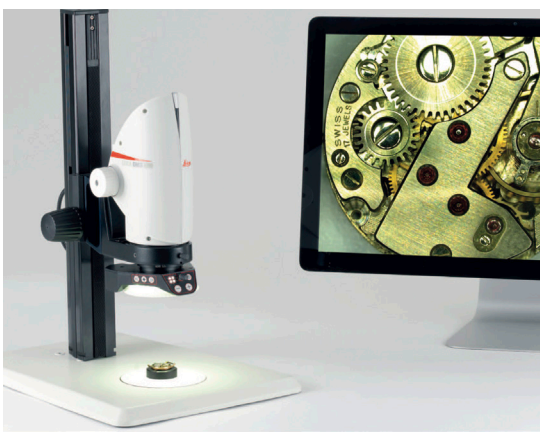
$$\text{Magnification} = \frac{\text{Dimension of feature in image}}{\text{Dimension of feature on actual object}}$$

Examples of a digital microscope and stereo microscope with eyepieces and digital camera are shown below.

Left: Leica M205 C stereo microscope fitted with the Leica DFC450 digital camera. The ant sample can be observed via the eyepieces or a display monitor (2 sizes shown) for image detection by the camera.

Right: Leica DMS1000 digital microscope utilizing different monitor sizes for image display.





There is always the question if this level of magnification, 20,000 x, is simply beyond the useful range, meaning, is it **empty magnification** where no further details are resolved? What determines a useful range of magnification for digital microscopy, where an image is observed via display on a monitor? There are 2 main factors: the microscope system resolution and the image viewing distance.

Microscope system resolution

The system resolution for a digital microscope or microscope with eyepieces operated with a digital camera is influenced by 3 main factors:

› Optical resolution from the objective, zoom, tube, and camera mount lenses
› Image sensor resolution from the camera chip
› Image display resolution from the electronic monitor.

The resolution limit of the digital microscope system is determined by the smallest of the 3 resolution values above.

Useful range of magnification

First, it is assumed that the viewing distance, the distance between the eyes of the observer and the displayed image, is always within the useful range. The **useful range of viewing distance** is based upon a conventional reference of 25 cm, the average nearest point for the human eye where clear focus is possible.

The useful range of magnification for digital microscopy can be defined as:

$$\frac{\text{System resolution}}{6} < \text{Useful magnification} < \frac{\text{System resolution}}{3}$$

Thus, the **useful range of magnification** is between $^1/_6$ and $^1/_3$ of the microscope system resolution.

Modern camera chips often have pixel sizes well below 10 µm and modern monitors pixel sizes well below 1 mm. At high magnification from the sample to the camera chip, for example 150x, then the microscope system resolution is determined by the optical resolution limit. The optical resolution limit for the largest numerical aperture, 1.3, and the smallest wavelength of visible light, 400 nm, is about 5,400 line pairs/mm. The **maximum magnification** which falls into the useful range defined just before is **1,800x**.

At very low magnification, for example below 1x from the sample to the camera chip, the numerical aperture is usually quite small, however the resolution limit of camera chips with pixel sizes larger than 2 µm and of monitors with pixel sizes larger than 0.5 mm will normally be less than the optical resolution. Therefore, at very low magnification, the chip or monitor resolution limit is often the dominating factor.

Empty magnification

Whenever the magnification value exceeds the useful magnification range for digital microscopy, 1,800x, this results in empty magnification where the image appears bigger, but no further details about the sample can be resolved. A magnification of 20,000x is far beyond 1,800x, so clearly it is empty magnification.

Conclusion

For digital microscopes, as for other optical microscopes, there is a clear limit on the useful range of magnification. Going beyond that magnification range, in other words exceeding 1,800x, only results in empty magnification. To understand the useful range of magnification for digital microscopy in more detail, please refer to the technical report cited below as additional reading.

Additional reading

DeRose, J.A., Doppler, M.: What Does 30,000x Magnification Really Mean? Some Useful Guidelines for Understanding Magnification in Today's New Digital Microscope Era. Leica Science Lab, February 2015

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