

DIGITAL IMAGES

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DIGITAL IMAGING CONCEPTS

- 1 Digital images are pictures stored as numbers
- 2 Comparing images of the same object at different times reveals motion
- 3 Filters enable a black-and-white camera to distinguish different colors of light
- 4 Computer manipulation can enhance images and reduce distortion

Find out how images can be stored as digital pictures. These pictures can then be analyzed and manipulated by a computer. Explore these concepts further using the recommended resources mentioned in this reading selection.

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Digital images are pictures stored as numbers

Accurate pictures of distant light sources are crucial to the science of astronomy. But for most of history, the only way to record an image was to describe it in words or to draw a picture. Despite these limitations, the careful drawings made by astronomers long ago reveal a great deal about the movement and changing appearance of celestial bodies.

The invention of photography in the 19th century made recording astronomical images much easier and far more accurate. From the 1880s to the 1970s, photographic film was the dominant medium for storing astronomical images. Since then, however, astronomers have primarily recorded images as digital information on computers.

A digital image is a picture divided into a grid made of small dots called pixels. Every pixel in a digital image is assigned a numerical value. One advantage to this is that the entire image can easily be translated into a string of numbers. A computer can then recreate the image from these numbers at any time.



Try this Resource!

Pixel This! shows students how to decode a simple digital image from a string of numbers that represent pixels. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u07_pixel.pdf



If you're visiting the Moveable Museum, you can explore how digital images of cosmic objects can be manipulated by computers to make remarkable discoveries.

Digital Cameras and CCDs

Although a digital image can be made by converting a conventional photograph into pixels, this is not the most efficient method. Today's digital cameras can record images directly as digital information. Many of these instruments, including video cameras, photocopy machines, and fax machines, detect light using charged-coupled devices, or CCDs.

A CCD is made of thousands—or even millions—of tiny light detectors arranged in a regular pattern, like squares on a piece of graph paper. The amount of light that strikes each pixel on the CCD is recorded in the form of an electric charge. The brightness of each part of the image is then converted directly into electronic information. The electronic information created by CCDs can easily be processed, analyzed, and compared with other digital images by a computer.



Numbers composed entirely of ones and zeros, or binary numbers, are preferred for encoding digital images because binary numbers are easiest for computers to process. Any number can be represented as a string of ones and zeros. Here is how the numbers 1 through 15, for example, are written in binary numbers:

1: 0001	6: 0110	11: 1011
2: 0010	7: 0111	12: 1100
3: 0011	8: 1000	13: 1101
4: 0100	9: 1001	14: 1110
5: 0101	10: 1010	15: 1111

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Comparing images of the same object at different times reveals motion

One of the first people to study the sky with a telescope was Galileo Galilei. When Galileo pointed his telescope at the Sun, he became the first European to discover sunspots. Galileo sketched the location of these sunspots on successive days. By comparing these pictures, he noticed that the sunspots seemed to march across the Sun's surface. From this, he correctly deduced that the Sun was rotating.

Around the same time, Galileo turned his "spyglass" on Jupiter. Again, he recorded his observations as sketches. By comparing sketches made on different days, he observed four small points of light whose position constantly changed, although they always remained near Jupiter in the sky. Galileo concluded, again correctly, that he was observing moons in orbit around Jupiter. Galileo made both of these profound discoveries in 1610.

Photography has made it much easier to detect subtle changes in astronomical images. Astronomers take photographs of the same region of the sky on different days. In most cases, these pictures look the same. But occasionally, the position of one tiny point of light will change markedly. This movement may mean that the point of light is not a star at all, but a closer object such as a planet, an asteroid, or a comet. Additionally, changes in images over time can also reveal a star growing brighter, or seemingly appearing out of nowhere. This can indicate that a distant star has exploded in a brilliant supernova.

Astronomers used to spend thousands of hours poring over photographs in search of asteroids and supernovae. Nowadays, digital cameras have made it much easier to compare astronomical images. Digital images are translated into data that can be analyzed by computers. Computer programs compare the numerical values for every pixel in the image in search of significant differences. In 2001, digital image processing made it possible for astronomers to discover eleven previously unknown moons of Jupiter in a single year!

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If you're visiting the Moveable Museum, you can use the Hands-On Universe computer kiosk to manipulate digital images of cosmic objects in much the same way as astronomers do.

3

Filters enable a black-and-white camera to distinguish different colors of light

Your eye detects different wavelengths of light as different colors. Specific cells in your retina are sensitive to red, green, and blue light. Your brain analyzes how much light was detected in red, blue, and green wavelengths by these cells and combines the results into a single color image.

CCD chips work differently. They can measure only the intensity of light, not its color or wavelength. A CCD can still be used to take color pictures, however. The secret lies in using color filters.

Color filters allow only certain wavelengths of light to pass through them. For example, a red filter lets red light pass through it, but not blue or green light. Since white light is a mixture of all wavelengths of light, a beam of white light passing through a red filter will seem to come out as red light. But the filter does not change the white light passing through it into red light; it simply removes the wavelengths that are not red. If there is no red light in the mixture, no light will pass through it at all.

To take a color picture with a black-and-white light detector, you take three pictures—one with a red filter, one with a blue filter, and one with a green filter. The images recorded will all be black-and-white, but each will show how much light the object emitted in particular wavelengths. For example, the amount of red light coming from any part of the object is represented by the brightness of the image taken with the red filter. By replacing the brightest areas of each picture with the color it represents, you can combine the three images to create a color picture.

Filters can also be used to record how much light an object gives off in one specific wavelength, such as the characteristic wavelength of a particular chemical element. By isolating that wavelength of light from the total light in an image, the filter can expose the exact locations where that element is present.

Without filters, a planetary nebula looks like a blob of glowing gas. But when the wavelengths emitted by specific elements are selectively filtered, hidden details appear. Filters that block all wavelengths except those emitted by nitrogen can reveal rings of nitrogen gas circling stars. And filters that distinguish between oxygen and hydrogen can reveal hotter and cooler spots in a nebula.



Try this Resource!

Filtering Light demonstrates how color filters work and how they are used in creating astronomical images. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u08_filtering.pdf

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Computer manipulation can enhance images and remove distortion

Computers can manipulate digital images in many different ways. The image can be altered to highlight information that would not otherwise be visible. Computer enhancement can also remove distortion from an image.

“False-Color” Images Emphasize Information

Sometimes when making an image, an observed wavelength of light is replaced by a different color. When astronomers use a filter to observe nitrogen gas, for example, they display the nitrogen image using colors that are not necessarily realistic. The image represents what the object is made of, even if the colors are not what you would observe with your eyes. An image made from colors that were not originally present is called a false-color image.

False-color images can reveal forms and structures that cannot be seen in visible light. For example, a camera might take a picture of the ultraviolet light emitted by the Sun’s corona—the jets of gas that shoot out of the sun like a crown. Because ultraviolet light is invisible to our eyes, a false-color image must be created to represent what our eyes cannot see.

False-color images are also used to make small differences more apparent. For instance, slight variations in wavelength that cannot be detected by your eyes might be represented as completely different colors in the image.

Computer Manipulation Can Remove Distortion

All telescope images suffer from a certain amount of distortion. The limitations of instruments such as lenses, mirrors, and CCDs cause images to blur. And all images taken from Earth suffer distortion because of the Earth’s atmosphere. Through digital image processing, computers can remove some of this distortion.

Distortion is removed by determining exactly how it changed the observed light, then performing a mathematical operation on the data from the CCD to cancel out this distortion. To determine the distortion of an image, astronomers make a second image of a well-known reference star for comparison. They know exactly what this reference star should look like, so they can estimate how badly it was distorted by the Earth’s atmosphere. They then assume that the same distortion occurred in the original image, and adjust the second image accordingly. In this way, some of the blurring effects of the atmosphere can be removed.

Computer enhancement can also combine several pictures taken by the same CCD. It can also remove background signals, or static, from an image. In some telescopes, data from several mirrors are combined into a single image by a computer. New types of computer enhancements are constantly being developed, so the quality of the images available to astronomers is constantly improving.