NDT

Film at 11!

Understanding the terminology will help determine what is digital and what is not.

By George McLachlan

In the nondestructive testing (NDT) X-ray world, terms are regularly used, abused and generally misused. The two most significant terms are real-time and digital. The terms seem pretty straight forward, but consider that not all digital systems are real-time, and not all real-time systems are digital.

The elements of an X-ray imaging system include an X-ray source and an image-capture device. The X-ray source produces X-ray, but the rays are not comprised of zeros (0) and ones (1) and so it is not digital. The most relevant effect the source will have on the real-time process is related to the focal spot size, as referenced in ASTM E 1255 Paragraph 6.1.1.2 Geometric Magnification. Small focal spots allow greater magnification.

The image-capture device can be film, film replacement Computed Radiography (CR), image intensifier with some scintillator materiel to convert X-ray to light. It can also be a detector panel with some scintillator materiel to convert X-ray to light or the X-ray energy, and some material that is charged by X-ray. Now here comes the rub; the conversion process of X-ray to light or energy is not digital, but becomes digital as the result of an analog to digital (A to D) conversion to produce a digital image.

The CR systems store the X-ray energy on a photostimulable phosphor plate that emits the stored energy when stimulated by light. This process also produces a digital image. When processed by a film digitizer, film will also produce a digital image that can be displayed on a computer.

Digital X-ray is probably more correctly described as a digital image generation process that requires some type of A to D conversion. The earlier in the process that this A to D conversion takes place, the better.

Film or non-film

Basic image-capture types are either film or non-film. Non-film can be real-time or non-real-time. Images can be digital or non digital. An image is definitely digital if it has pixels.

Pixels are the smallest discrete element of an image or picture on a cathode ray tube (CRT) screen. The greater the number of pixels per inch, the greater the resolution.

The size of a pixel on a panel-type receptor is generally in microns, but with geometric magnification, which is allowed by using a mini focus or micro focus X-ray tube, a 127-micron pixel can effectively become a 12.7-micron pixel when 10X magnification is used. So in theory, the

A piece of pipe is analyzed with this digital X-ray system. Joysticks move the part through 5 axes while the operator looks at the part on the screen, in real time.
Photo: David Pugsley

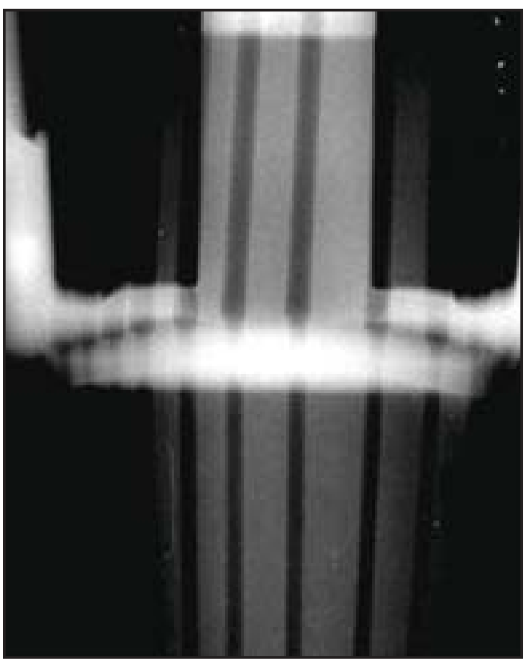
smallest detail that can be resolved is 12.7 microns. Using 100X geometric magnification when using a micro focus tube (10 micron focal spot or smaller), the effective detail that can be resolved is very small.

After understanding the role of the computer and the pixel, the next component of a non-film capture type is the bit. Bits are the mathematical term used to represent the process of digital processing. The definition of a bit is binary decimal, meaning that a single digit in the binary number system with a value of either 0 or 1.

The significance of the bit is that the A to D conversions are based on the bit rate of the conversion and determines the shades of gray the resulting image will have. By knowing the conversion rate of a digital image, the number of available gray scales is known.

The binary number system used is base two. A number representation of 0 and 1 is used by most computers because of its ease-of-implementation using digital electronics and Boolean algebra. Looked at in a different way, if a bit is base two, and it is 0 or 1, then the number 2 is the constant. So if it is an 8-bit A to D conversion, the number of gray scales is equal to 2^8, or 2 raised to the eighth power, and this is equal to 256 or 256 gray scales available.

The intersection of cooling holes in the middle of a large turbine blade is inspected to ensure that the holes intersect. In this image, one of the holes intersects too far to the right. *Photo: David Pugsley*



The Hierarchy: Real-Time to Digital

Real-time systems are defined as inspection systems that are at least 30 frames per second of image acquisition. The hierarchy of a real-time system going to digital looks something like this:

The basic system consists of:
- Image intensifier
- CCD Digital Chip Camera; it is an RS170 composite video (analog)
- Monochrome TV monitor

The enhanced basic system consists of:
- The basic system with a computer-based image processor.

The advanced enhanced system consists of:
- High resolution image intensifier (25 millimeter or larger output phosphor)
- Digital camera—12 bit or more
- Advanced image processing system
- High resolution monitor (mega-pixel)

The basic detector based system (not true real-time) consists of:
- Amorphous silicon sensor array
- Gadolinium oxysulfide or cesium iodide scintillator
- Basic image processor
- High resolution monitor (mega-pixel)

Enhanced detector based system (true real-time) consists of:
- Amorphous silicon sensor array
- Gadoliuium oxysulfide or cesium iodide scintillator
- Enhanced image processor
- Two high-resolution monitors (Mega-pixel)

Image intensifiers and detector panels come in different performance levels and sizes. Cameras used on an Image Intensifier come in different performance levels and levels of A to D conversion. The formula for A to D conversion is:

8 bit = 2^8 or 256 shades of gray (analog)
12 bit = 2^{12} or 4,096 shades of gray (digital)

Digital cameras come in 10- and 12-bit models. Monitors come in different levels of resolution. Computer monitors, for instance, are characterized by pixel size, and TV-monitors are characterized by lines per inch.

Silicon panels, or Amorphous silicon detectors, come in two basic sizes: 9.4 by 10.5 inches and 11.1 by 14.4 inches. They also come in 12- and 14-bit varieties.

Image processors are available in several levels from a basic system that does filtering and some level of integration to advanced systems that perform measurement, save images to their hard disk, CD and are networkable.

The selection of the elements of any system is important. The performance of the system will be only as good as the lowest performing element of that system.

The real-time digital X-ray technology can inspect both the length of the blade, as seen here, and the hole intersections at the same time. Film would require two or more exposures. *Photo: David Pugsley*

Of note, most 8-bit cameras used on image intensifiers have an analog output called composite video and most 10 bit or higher cameras have a digital output.

What can it do?

To better understand what real-time digital X-ray systems can mean for an application, a good analogy might be the evolution of the camera. Film requires chemicals and takes time to get results. Film-type cameras require the film be sent out to be developed, which takes time. When the "prints" come back, sometimes they are good pictures and sometimes they are not. With the advent of Polaroid cameras, the picture is available sooner, but again the result could still be good or bad. The digital camera came along and when a picture is taken, the quality of the picture can be immediately seen. This is more like real-time.

Real-time digital X-ray provides fast and accurate results. The purpose of X-ray inspection is to determine if a product is acceptable. It also should be a tool to provide process control to ensure that a process such as casting or welding is producing the desired result. And so, faster means shorter process time, higher productivity and better bottom-line results. But, the results and performance improvement depend, in some measure, on the type of system that is selected.

Using all the information will aid in system selection. Keeping in mind that all real-time systems are not digital, and all digital systems are not real time, consider that:

- Real-time digital X-rays will permit in-motion inspection of at least 30 frames per second of image acquisition.
- All image acquisition technologies require an A to D conversion to become digital. This conversion is a measure of available gray scale and is based on the base number to the power of the conversion. Or more simply stated, 12 bit is 2^{12}, which has 4,096 or a dynamic range of 0 to 4,095.
- A pixel is the smallest discrete element of a digital image, and the greater the number of pixels per inch, the greater the resolution. A pixel is also sometimes referred to as a picture element or pel.
- Geometric magnification can be useful, especially if looking for something that requires a small focal spot.

A real-time radiographic cabinet system. Real-time digital X-rays permit in-motion inspection of at least 30 frames per second of image acquisition. *Photo: David Pugsley*

A sample is loaded onto the 5-axis manipulator. It puts the part between the X-ray source and the image-capture device. *Photo: David Pugsley*

The three most prevalent acquisition technologies that purport to be digital are:

• Storage Phosphor or CR is a photostimulable phosphor plate that retains the energy from X-ray and releases it to a reader that uses light.

• Amorphous Selenium or DR is a selenium layer in a panel that is charged by X-ray that is read by a thin film transistor array.

• Amorphous Silicon is a panel with a scintillator that converts X-ray to light that is read by photodiodes or thin film transistor array.

Real-time X-ray, digital or not, is here to stay. It provides a modality to accomplish the NDT inspection of product without the need of chemicals and film storage. X-ray systems will provide results that will meet or exceed requirements. **NDT**