**Term list: Informatics Session 5, Digital Imaging, v. 1.0**

Area scanning

A procedure for microscope slide scanning in which the scanning device uses a standard digital camera sensor to image contiguous rectangular or square fields of view on the slide (also called tiles or patches) and then stitches those areas together in software to make a whole slide image.

Annotation (image)

Data added to an image by an algorithm or observer. Annotations may be text or images and become part of image metadata. Examples include color overlays or borders for regions or cells of interest.

Anti-aliasing

Blending the colors of a narrow row of pixels along a color boundary in a raster image to smooth the appearance of the boundary edge.

Aspect ratio

The overall shape of an image (e.g., wide, tall, square, etc.).

Color calibration

A procedure for adjusting the colors shown by the display to match the original colors of the microscope slide. Uses methods and standard calibration slides developed by the ICC (International Color Consortium).

Color depth (bit depth)

The number of bits that are used to represent the color of each pixel in a digital image, which defines the number of different colors that can be represented. In a typical grayscale image, each pixel can have one of 256 levels of brightness represented using 8 bits (one byte, 0-255 in binary). Some radiology systems expand the bit depth to 10 bits per pixel, allowing 1024 gray levels. In a full color image, the brightness of red, green, and blue (RGB) in each pixel is represented by 8 bits (256 brightness levels) per color, so the color or bit depth of the image is 24-bit (8x3). The RGB brightness levels are mixed to yield a total of about 16.7 million different colors. Some image formats offer additional special features requiring additional bits per pixel, such as pixel “transparency.”

Color gamut

The range of colors that an output device (eg, a scanner or display) can produce. Accurate color reproduction requires matching or mapping scanner and display color gamuts.

Compression (file compression)

Representation of image data as mathematical functions that can be used to reconstruct the pixel display and can be stored in smaller data files than individual representation of all pixels.

Compression artifacts

In lossy image file compression, the image inaccuracies that are produced either by over-compressing an image or by repeated display and compression of the same file.

DICOM

Digital Imaging and Communications in Medicine. A standards organization and the standards they produce for formatting and communicating medical images. Radiology devices have long used the DICOM standard, which allows devices from multiple vendors to work together. DICOM image files contain both textual information and image (pixel) data, and the image data may be coded in several formats including compressed images. DICOM specifications for color images in pathology are being developed.

DICOM frames

Segments of pixel data in a DICOM image file. The frames are related to positions in the image and can be accessed separately so that a particular field of view can be accessed without needing to send the entire image to the viewer.

DICOM header

Textual and numerical data at the beginning of a DICOM image file. Contains metadata about the image including patient and study information, optionally a clinical interpretation of the image, image annotations, the shape of the image and position of the pixel frames in the image, and information about the format of the image data.

FDA approval of pathology imaging systems

To date, the FDA has approved only a limited number of digital pathology systems for primary diagnosis. Because the devices, software, and communications are not standardized, the FDA has approved only particular sets of devices that are to be used together without the possibility of substitution, ie, particular scanner, software, and display models and versions. As standardization progresses approvals are likely to become more flexible. Note that laboratories can assemble their own sets of devices and validate them as lab-developed tests (LDT) without FDA approval, but the required validation is more demanding than verification of performance of an approved system.

Field of view (FOV)

The displayed portion of a larger image.

High throughput scanner

A high-speed microscope slide scanner with slide auto-loading that can be used in an automated workflow to scan routine histology lab output. Current high throughput scanners require as little as 30 seconds per slide and can be loaded with over 400 slides.

Image file size

For a particular magnification, the size of pixel data for a tissue section with a defined area can be calculated as:

(color depth) x (tissue area) / (pixel area @ magnification)

Image pyramid

An image file and database design where a high-resolution image (eg, 20x or 40x) is associated with several lower resolution images corresponding to lower magnifications, produced by subsampling the high-resolution image. The highest resolution image may also be scanned at several levels of focus (“Z levels,” especially for cytology). The image pyramid allows lower resolution images to be accessed and transmitted quickly when higher resolutions are not needed and avoids scanning multiple times for different magnifications (since the lower magnifications are produced mathematically from the higher magnification image).

JPEG, JPG

Joint Photographic Experts Group. A data standard for variable, lossy compression of raster images and a file format for the compressed images. Especially effective for photographs including photomicrographs. Represents blocks of pixels as functions that can be stored compactly and used for recreation of the pixel blocks, though not perfectly. Standard JPEG uses discrete cosign transform. JPEG2000 is an update of JPEG based on a wavelet transform that has some quality and compression advantages over the original. JPEG compression can be used in DICOM images.

Line scanning

A procedure for microscope slide scanning in which the scanner uses linear array of sensor elements to progressively image a slide in broad strips. Generally faster than area scanning but until recently not sensitive enough for fluorescence microscopy. TDI (time delay integration) scanners stack several linear arrays in sequence to provide multiple passes over each area of the slide, yielding adequate sensitivity for fluorescence.

Lossless compression

A method of raster image file compression that regenerates the original image perfectly without artifacts. Lossless compression does not offer variable degrees of compression. Best for graphic art and other applications with broad areas of identical color. Doesn’t compress complex color gradients well, such as those found in photographs and photomicrographs. PNG (portable network graphics) files are the most common form of lossless compression currently encountered. GIF files are an older, similar format.

Lossy compression

A method of raster image file compression that regenerates the image in a form that is usable but contains minor artifacts. Can be particularly good for photographic images (more than 15-20 fold compression with very limited artifacts). May offer variable compression in which the degree of compression can be balanced against production of artifacts. Can accumulate artifacts and degrade if images are displayed and re-compressed repeatedly.

Metadata

Literally, “data about data.” For images, the primary data is the pixel data. Image metadata includes date/time, patient, case, interpretation, annotations, etc.

Multispectral scanning

A scanning device that can tune its camera to specific wavelengths or sets of wavelengths while ignoring others. Allows mapping and separate viewing of the positions in the same tissue section of specific stains or antibodies with reporter groups that pass or emit (as fluorescence) different wavelengths.

PACS

Picture Archiving and Communications System. A database designed for storage and retrieval of high-volume image data, and for support of image viewers and their tools. This terminology is widely used in radiology and may become standard in pathology as those systems develop. These databases typically index images based on patient and case metadata (the data in DICOM file headers) and can retrieve partial pixel data related to fields of view to save network bandwidth. They may communicate with APLIS for additional clinical data and for upload of image interpretations.

Pan

Move the field of view horizontally or vertically in the plane of the slide.

Pixel

Short for picture element. The smallest element (a single dot) of a raster image. In a luminous color image such as a computer screen, a pixel emits a mixture of red, green, and blue (RGB) that is perceived as one color. Although not relevant to purely digital pathology, pixels printed on opaque, non-luminous material like paper reflect light and are mixtures of cyan, magenta, yellow, and black (CMYK with “K” standing for black to avoid confusion with blue). Luminous images are referred to as “additive” because the component colors add together to make the perceived color. Reflective images are referred to as “subtractive” because the component colors absorb their wavelengths from the incident white light, and the leftover (remaining) light creates the perceived color. Each of the three colors for pixels represented as RGB is represented by one byte (256 levels of color intensity) requiring a total of 24 bits of storage. Some software may add data elements other than color to each pixel, transparency for example, which increases the per pixel memory requirement.

Raster image

An image composed of small dots (pixels) of different brightness or color that, when arranged correctly, reproduce a visual scene. Raster images are sometimes called bitmap images. Smaller dots relative to the elements of the scene allow depiction of greater detail, and the number of dots in the image is referred to as the image resolution. Computer programs like Photoshop are designed to work with raster images.

Resolution

The number of pixels in a raster image, usually indicated as horizonal and vertical measurements (eg, 1024x768 pixels). This differs from optical resolution, which is smallest distance at which separation between objects can be perceived. In microscopy, optical resolution is related to the numerical aperture of the lens and the wavelength of the incident light. In photomicrographs, the size of the pixels relative to the original tissue is an important aspect of resolution. The approximate size of photomicrograph pixels is 0.5 µm2 at 20x magnification and 0.25 µm2 at 40x magnification. Slide scanners should have complementary optical and pixel resolution, since overall resolution will be limited by the poorest of those values.

RGB

Red, Green, and Blue, the three colors that are combined to produce the visible range of colors in luminous images. See Pixel and Color Depth.

Slide scanner

A device for creating digital images of whole microscope slides. Slide scanners may have multiple slide storage with autoloading and a barcode reader for identifying slides, and they include a light source, scanning stage, lenses, a digital camera or linear sensor array, and associated computing capability to assemble and transmit the images. Scanners may have static or changeable lenses (usually 20x and/or 40x) though oil immersion is available on some. Scanners may also allow fluorescent and multi-spectral scanning. Previously scanners were dedicated to a particular type of imaging (eg brightfield vs. fluorescent, dry vs. oil lenses) but multi-function scanners are beginning to appear.

Slide viewer

A client software and display system that is optimized for working with and interpreting whole slide scans. Most current viewing devices are designed for a particular whole slide imaging system, but general-purpose viewers are likely to be available in the future. Viewers may implement software tools designed to improve pathologist consistency and efficiency.

Subsampling

In digital imaging, a technique for reducing an image’s resolution by copying an evenly distributed subset of the image pixels, usually with averaging across adjacent pixels. Used to construct the smaller, lower resolution images in an image pyramid from the base high resolution image without needing to rescan at lower resolutions.

Telepathology

Technically, pathology-at-a-distance using electronic transfer of images. Most common implementations use static or streaming images from a microscope with a camera that may be controlled by a technician, or robotically controlled at a distance. May or may not save the data streams once an interpretation is rendered. Likely to be replaced by whole slide imaging once that technology is well-established and lower cost.

Thumbnail

A small displayed image used for representation, identification, and selection of larger images.

TIFF

Tagged Image File Format. An image file format commonly used for scientific applications, high resolution graphic art, and publishing. Each file can contain multiple images and the pixel data can be stored uncompressed or compressed with lossless or lossy algorithms. A TIFF file can also contain a compressed JPEG image. TIFF files contain a header that identifies the file type and provides an offset to the first image file directory (IDF). Each IDF contains a list of standard name-value pairs (“tags”) that describe its associated image and provide an offset to the start of the image data. Image data is stored as “strips” (regions) of the image and may or may not be compressed as specified in the IDF.

Validation of imaging systems

The College of American Pathologists (CAP) recommends that whole slide imaging systems be validated after installation and setup, using a workflow similar to the intended production workflow and at least 60 cases of a variety of types for each application (eg, primary diagnosis with H&E images). The same observers should interpret both glass and electronic images, there should be a two-week washout between the two interpretations, and the order of presentation of cases should be randomized.

Vector image

An electronic image in which the contents are defined by equations for lines and shapes to be displayed. Vector images don’t have an inherent resolution like raster images. Instead, on display the shapes in the image are drawn to the highest resolution of the current display device. Because vector graphics don’t represent pixels individually and their contained shapes may define the appearance of many pixels all at once, vector graphics files can be much smaller than raster image files. Computer programs like PowerPoint and Illustrator are designed to work primarily with vector graphics, though objects containing raster images may be pasted in.

Whole slide imaging (WSI)

Often used synonymously with “digital pathology.” Technically, WSI is the production of electronic images of microscope slides that can substitute for the slides in diagnosis. In common usage, WSI refers to a strategy and workflow for anatomic pathology image acquisition, review, and interpretation that uses digital hardware, software, and network communications to convert microscope slides fully to digital images and, in combination with data from the APLIS, allow accurate and efficient signout from electronic display only.

Z-levels

Digital images obtained from the same tissue section at multiple levels of focus (eg, at multiple closely-spaced positions on the Z axis, perpendicular to the slide). Overlaying these images in a viewer to allow an observer to simulate focusing up and down is sometimes called “Z-stacking.” Z-levels and Z-stacking may also be used to refer to assembly of images from vertically-spaced sections of the same tissue sample to yield a 3-D reconstruction of the tissue.

Zoom

Change magnification between levels of the image pyramid, especially if it is done smoothly by interpolating between the images.



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