Digital Signal Processing and Medical Imaging

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Abstract

Medical imaging and digital signal processing are two technologies that have merged together very well and have given standard diagnostic tools more power for healthcare providers. This has lead to better treatment of patients which in turn means a better quality of life. This paper reviews the medical imaging process, how digital processing improves the process, and how the internet has helped in the transmitting of images.

Introduction

Medical imaging is a powerful tool for healthcare providers in the diagnoses and treatment of patients. As with many tools that are used in healthcare the technology, this tools has changed over the years. Medical imaging is one of the fields that has seen new technology used with old tools. For example, a simple X-ray is no longer the complex process that it was before. Formerly, when a patient would receive an X-ray, film would be placed under the area which was to be X-rayed. A technician would shoot the picture, the film would be developed, and then the X-ray would be read by a radiologist. Today, technology has streamlined the process by removing the film aspect. Filmless X-rays make the handling of X-rays less complex and the transferring of information between healthcare providers easier. A newer imaging technologies, such as CT and MRI systems, which give a better and more detailed pictures, have been updated also. Digital imaging gives healthcare providers better and more accurate images, which leads to establishing diagnoses sooner, making treatment of the patient more successful.

Overview of operation

The process of receiving an X-ray remains the same; however the process of developing, reading, and sending the image is different. A phosphorus plate is placed

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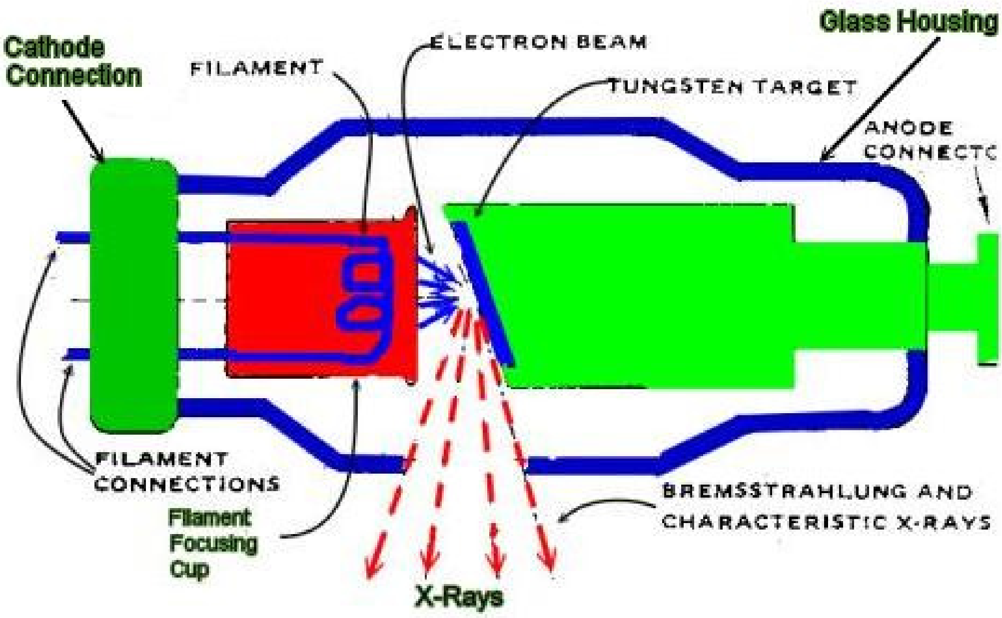

Figure 1: The Chart of Image Processing

inside a Buckeye bucket which is located inside of the X-ray bed or on a pedestal, and the target area is place over the plate. The strength of the beam radiation is measured in kilovolts, while duration of the radiation is measured in milliamps.

In the next step of the process, the technician makes an exposure, starting the X-ray process. Negative charged electrons move from the cathode of the X-ray tube to the positivity charged plate. When these electrons hit the tungsten plate they deacelerate and X-rays are produced. The X-ray beam is sent through a glass hole inside of the X-ray tube. This beam hits the target area and then passes through the object being X-rayed. Because of the different densities of the target area, the X-ray excites the phosphorus on the phosphorus plate with different intensities which produces a picture of the target [1].
The phosphorus plate is removed from the Buckeye bucket and placed inside of a processor. The processor scans the phosphorus plate with light and detects the amount of energy that has been stored. The different energy levels are assigned to different numerical values and the software of the processor produces a picture in gray scale. The digital information of the X-ray is placed in an industry format and saved using information technology. The phosphorus plate is reformatted by being exposed to a very bright white light which de-excites the phosphorus. The plate is then reused [2].

The CT scan and X-ray use the same physical process to produce a picture; however, the CT scan is done differently. The emitter and detector are placed one hundred and eighty degrees apart and spin in a vertical circle around the target while the target is moved through the circle. The emitter produces the beam while the detector detects energy that is transmitted through the body, which is then processed. Other imaging tools such as MRI and ultrasound work on the same basic principle where signals are been transmitted, received and then processed [3].

Image Noise

Image noise is regarded as any undesired by-product of image capture. Some sources of the noise are the data storage method, the output device which displays the image, imperfections in transfer of data (i.e. defective cables, corrupt file transfer, etc.), and the image environment. Image noise can be classified by several characteristics: Additive vs. multiplicative, signal independent vs. signal dependent, Gaussian vs. non-Gaussian, white vs. colored, stationary vs. non-stationary, among others [4].

For most image processing tasks, the noise is assumed to be additive and signal independent. If the noise is assumed to be white, then the only parameter of interest is the variance. For colored noise, the estimation of the spectrum is usually obtained by comparing the spectrum of images of uniform radiation fields that are taken during separate experiments with the same or similar sensors.

Histogram equalization is a technique that can be used to uniformly disperse gray levels in an image. This method is used to lower contrast and color intensity. Another less common practice is histogram specification, which allows the user to transfer the original histogram into an arbitrary shape defined by user input. This allows the user to control intensity levels, just like truncation or equalization, but involves high altering of the original image. This method is best used when specific contrast or color intensities are preferred in the output image. All three types of histogram manipulation involve the user changing the Look-Up Table (LUT) values for pixel contrast to user defined values; in other words, changing the intensity (probability) or pixel values of the original input image. Care must be taken to avoid saturation or manipulating the color gamut too much, unless these effects are desired [5].

An image will often have one or more noise effects within itself. Quantization noise in an image is defined as unwanted artifacts caused from quantizing a continuous variable. Theoretically, image subjects are continuous in space and time so their images are continuous. When these images are quantized, undesirable distortions may occur. Many of these effects can be minimized or altogether removed using various noise reduction (filtering) techniques. Filtering may also be used to enhance certain characteristics of an image, for various reasons, to achieve desired output image that accentuates one image characteristic over another, i.e. edging or sharpening. Some of the more common filter types are discussed below [6].

Filter Types

Gaussian blurring or smoothing is used in image filtering to grayscale or “tone down” an image. Blurring is used when the user wishes to minimize the visual effect of edges or contrast sharpness, effectively blending the image’s contrast. Smoothing is generally the same concept, filtering the image to "smooth" the color or grayscale transitions. Smoothing and blurring are also effective in removing high noise interference in the signal, maximizing the signal-to-noise ratio (SNR). The effect visually eliminates signal noise and preserves the original signal [7].

Embossing is a common technique in print and media, but is also used in image processing. This type of filtering works best in black and white images or grayscale, but can also be applied to color images.

Sharpening and unsharp masking are nearly opposite filtering techniques used to accomplish the same result. Sharpening removes lower frequencies from the image, preserving only the "sharper" frequencies of the original input image. Unsharp masking removes all lower frequencies below a cut-off value, preserving and amplifying only the higher frequencies of the original. This blurred, unsharp positive is then recombined with the original negative to create a masked image over the original image. Another similar filter is the high-boost filter, which works on the same principal as the unsharp mask but is more generalized [8].

Edge detection is a very popular filtering tool. This type of filtering defines an edge as a sharp gradient. The gradient must meet or exceed some gradient change value (T) in order to classify as an edge. There are two ways to modify the input image to attain a minimal threshold T; we can either increase the value of T or detect local extremes. Both instances involve making T larger since we desire to minimize the production of false or wide edges.

Warping is another useful tool, especially in images that have barrel distortion. Barrel distortion is when the image falsely warps the dimensions of the actual subject, i.e. an image of a rectangular object looks curved instead of straight.

Until now, only max/min filtering has been discussed where median values were typically unnecessary. We will now focus on median filtering, where noise reduction requires determining a median value to use for the entire image. Two such noise types include uniform white noise and Gaussian noise. Uniform white noise (a subset Gaussian noise) adds, as it's name suggests, a value of noise that shifts the pixels of the entire image towards higher luminosity. Typical Gaussian noise is noise added to the image that affects only a portion of the image [9].

Salt and pepper noise is noise that creates white and black pixilation in the image. This can result from incorrect quantization of pixel data. It is easily fixed by identifying a median pixel with which to balance the "salt and pepper" pixels to match the rest of the image. This filtering technique grayscales the black and white pixels with salt and pepper pixels of the image to match the surrounding/neighboring pixels.

Dust and scratches are a noise problems encountered most commonly in digitizing photographs or other film technologies. Dust will show up as spots and scratches are lines produced on the digitized image. Again, median filtering may be used, associating pixel values with neighbors to "smooth" the resulting image [10].

Weighted medians can also be used to filter an image in favor of one pixel value over another. Weighting pixel samples can be used in grayscale images to weight the contrast of the entire image with respect to a certain median pixel value. This technique can also be used in color images. The first of three ways to do this is by independently assessing each color channel; red, green, and blue. The center of gravity law makes this an acceptable method for linear median filtering of color images. The second method is taking statistical medians of the samples of the image with which to determine a median value. This is not the same as sampling each color channel separately, as that would introduce new (false) colors to the image. The third way is to add the filtering selectively to channels. Alternately, you could add the filter to the red and blue channels and not the green. The choice of which channel(s) to filter is left to the user [11].

Image standards

As the need for digital imaging and communication has medicine is increased, ACR (the American College of Radiology) and NEMA (the National Electrical Manufacturers Association) formed a joint committee to develop a standard for this technology. This standard is called DICOM and consists of a multi-part document. The document, the DICOM standard, contains the following sections: Introduction and Overview, Conformance, Information Object Definitions, Service Class Specification Data Structure and Encoding, Data Dictionary, Message Exchange, Network Communication Support for Message Exchange, Retired, Media Storage and File Format for Data Interchange, Media Storage Application Profiles, Media Formats and Physical Media for Data Interchange, Grayscale Standard Display Function, Security Profiles, Content Mapping Resource, Explanatory Information, and Web Access to DICOM Persistent Objects (WADO) [12].

Introduction and overview

As stated above, with increasing use of computers in clinical applications, the ACR and NEMA recognize the need for developing standards for transferring images and information between devices manufactured by various vendors. These two organizations formed a joint committee for some specific reasons, such as:

1. Upgrading communication of digital image information.
2. Helping the improvement and expansion of picture archiving and communication systems.
3. Give permission to create diagnostic information data bases which could be analyzed by many devices.

The latest version of DICOM has major improvements compared to previous ones such as: it is suitable for a networked environment; it is applicable to an off-line media environment; it specifies how devices react to any changes in commands or data; the level of conformance is being cleared; it is designed as a multi-part document; it identifies many different types of information such as images, graphics, waveform, report, etc.

Scope and field of application

This section introduces the history, scope, goals and the structure of the standard. DICOM has the capability of accelerating the interoperability of medical imaging equipments. It has specified a set of protocols for network communication, the syntax and semantics of commands which can be exchanged with aid of these protocols and it has specified a set of media storage services for media communication [13].

Goals of DICOM standard

In this section, we describe the purpose of DICOM standard as follows:

1. In order to have interaction between devices, a standard must be established to tell how the information moves between devices, and also notifies the user about the device reaction to command and associated data.
2. For offline communication, the DICOM standard addresses the semantics of file services, file format and other necessary information for this kind of communication.
3. The conformance requirements of implementation of the standard. is clearly expressed. A conformance statement should be able to specify the information to determine the appropriate function for device interpretability.
4. DICOM standard makes operation in a networked environment easier.
5. DICOM standard has the capability to support new technology for future medical imaging applications.
6. The use of existing international standards is applicable in this standard.

This standard has the capability of implementation of PACS (Picture Archiving and Communication Systems) solutions, and it is applicable in radiology, cardiology and in other medical environments.

Information object definition

The DICOM standard has defined two types of object classes: normalized and composite. Normalized information contains those attributes which are inherent in the real world entity. On the other hand, the composite information object class includes attributes which are correlated to the real world entity but they are not inherent.

Service class Specification

DICOM standard defines several service classes. DICOM also defines the common characteristics between all service classes and how a conformance statement to an individual service class is designed.

Data structure and semantics

The data set resulting from utilizing the information objects and services classes should be encoded and the DICOM standard should be able to do so. In this section, the necessary rules for transferring data are also explained.

Data dictionary

DICOM standard defines the elements used for media encoding along. For each element, DICOM specifies tag, name, and value. Then, for each item, it provides unique value, name, and definition of encoding and other useful information [14].

Message Exchange

This section on DICOM standard specifies not only the service for many applications, but also mentions the protocols used by an application in medical imaging environment for transferring messages between devices. It explains the operation and notifications, rules to establish and terminate associations, encoding rules, and so on.
Other parts in the DICOM are explained as follow:

DICOM supports network communication for message exchange. It specifies protocols and services for data communication and point to point communication; a general model has been specified for storage of medical imaging information on removable media. It also accelerates the interchange of information between applications in a medical environment; it specifies function for consistent display of grayscale images; it specifies security and system management profiles; it specifies the templates for structuring documents; and it specifies the methods which by using them a request for access to a DICOM persistent object can be expressed as an HTTP URL/URI request that includes a pointer to a specific DICOM persistent object in the form of its instance UID. The format of the returning result which will be returned in response to the request is also defined in the DICOM standard [15].

Conclusion

This document describes advantages of newer imaging technology such as CT and MRI. Image noise as a side effect of image capture is described in detail. Image noise sources are described and noise filtering techniques are discussed. The standard for digital imaging and communication is described with an overview of each section provided.

References

[1] Trussell, H.J., & Vrehl, M.L. Fundamentals of Digital Imaging, Cambridge University Press, 2008.
[2] Collenn, T. IBM Mayo Clinin speed up 3D medical imaging. Electronic News, 2007.
[3] Conley, N. PACS/RIS Administrator. (D. Midden, Interviewer), 2010, Janurary 4.
[4] Crompton, P., Smith, M., Leadbeatter, S., & James, R. Digital Imaging in the Forensic Post Mortem Room. Journal of Visual Communication in Medicine, 10-6., 2007.

[5] DICOM . (n.d.). Retrieved from DICOM : http://medical.nema.org/
[6] Jones, M. K. Two centuries of cystoscopy the development of imaging Instrumentation and synergistic technologies. Journal Compilation., 2008.
[7] Khelif, M. B. MRI Images Compression Using Curvelets Tansforms. Itelligent System and Automation 1st Meditewrranean Conference . American Institue of Physics., 2008.
[8] Kim, W. H. Ther future of digital Imaging . Communications of the acm., 2010.
[9] Mcullough, B., Ying, X., & Bonnefoi, T. M. Digital Microscopy Imaging and New Approaches in Toxicologic Pathology. Toxicologic Pathology , 49-58., 2004.
[10] Menegoni, F., & Pinciroli, F. A web management service applied to a comprehensive characterization of Vidible Human Dataset colour images. Medical Informanticd and he Interent in Medicine , 143-152., 2006.
[11] O.Kocsis. A toll for designing digita test objects for module performance evaluation in medical digital imaging. Med Inform , 291-308., 1999.
[12] Pavolpoulos, S. New hybrid stochastic deterministic technique for fast registration of dermatological images. Medical Biological Engineering & Computing , 777-786., 2004.
[13] Richard, W. Ditigal X-ray Imagers fill medical and NDT Task . Laser Focus World., 1999.
[14] Singh, S., V. Kumar, & Verma, H. DWT-DCT hybrid scheme for medical image compression . Journal of Medical Engineering & technology , 109-122., 2007.
[15] Vidal, F., FBello, Brodlie, K., John, N., Gould, D., & Avis, R. P. Principles and applications of computer graphics in medicine. Computer Graphics fourm, 113-137. 2006.

Biography

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