

## IMAGE PROCESSING OF CONVENTIONAL X-RAY IMAGES

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### ABSTRACT:

The goal of this paper is to outline the procedure of obtaining sharper and more visible images from a rejected X-ray. This process will improve X-ray image quality and produce image data that is more effectively displayed for a later visual imaging diagnosis. Image processing enhances image contrast thus increasing image visibility, helping both physicians and radiologists to make more accurate diagnoses and to decrease the need to retake X-rays. This in turn reduces the risk of radiation exposure and increases economical benefits by lessening the number of rejected X-rays. Different spectral and spatial enhancement techniques were used both in the spatial and frequency domain. The obtained X-ray images are sharper, more visible and recognizable, and provide much more information.

Key Words: X-ray Imaging, Image Processing, Medical Imaging.

### INTRODUCTION

The discovery of X-rays revolutionized the diagnosis procedure, and its importance can not be overemphasized. Radiographic quality refers to both image visibility and recognizability. The visibility of the image is best when its density is sufficient, its noise is minimal, and its contrast is maximum. It is most recognizable when its geometry is maintained, which takes place when sharpness is maximized and image distortion and magnification are minimized. Several factors affect the image quality, some of which are the focal-spot size, milliamperere-seconds, kilovoltage, field size limitation, patient status, contrast media, and film quality. Over the years the optimum parameters for a specific examination have been empirically determined by a large number of practitioners.

Tremendous efforts have been invested in upgrading X-ray image quality. A variety of techniques were developed, which were mainly concerned with hardware improvement, but their effects were limited. In the last decade computed tomography (CT) was developed. This system represents the state of the art in modern X-ray imaging. The CT system has major advantages as well as disadvantages. It maximizes both image visibility and recognizability, and it has a better resolution when compared to the conventional X-ray. The main disadvantage of the CT system is that it is too expensive to buy and operate, and only major clinics can afford it. In addition, it is less safe due to higher radiation levels and more expensive to the patients. For these reasons, the need for the conventional X-ray will continue for the next decade.

This paper expands the use of image processing techniques to improve the quality of conventional X-ray images without hardware modification. The only additional hardware needed is a digitizing device and a personal computer.

### BACKGROUND

X-rays were discovered in 1895 by the German physicist Roentgen and were so named because their nature was unknown at the time. Unlike ordinary light, these rays are invisible, but they travel in straight lines and affect photographic film in the same way as light. On the other hand, they were much more penetrating than light and could easily pass through the human body, wood and other "opaque" objects. We know today that X-rays are electromagnetic radiation of exactly the same nature as light but of very much shorter wavelength. The unit of measurement in the X-ray region is the angstrom ( $\text{\AA}$ ), equal to  $10^{-8}$ cm. X-rays, used in diffraction, have wavelengths lying approximately between the range of 0.5 - 2.5  $\text{\AA}$ , where the wavelength of visible light is on the order of 6000  $\text{\AA}$ . X-rays therefore occupy the region between gamma and ultraviolet rays in the electromagnetic spectrum (figure 1).

The method employed to produce X-rays is essentially the same as that used at the time of its discovery. A beam of electrons accelerated by high voltage to a velocity approaching the speed of light is rapidly decelerated upon colliding with a heavy metal target. In the process of slowing down, X-ray photons are emitted; the emitted X-ray is then directed to the human body. The number of X-rays that interact with the patient depend upon the thickness and the composition of the various tissues. Diagnostic X-rays interact primarily by the photoelectric and Compton processes. Photoelectric interactions are the most important for image formation because of the strong dependence of the photoelectric effect on the atomic composition of the absorber and the absence of long-range secondary radiations. Compton interactions are generally detrimental in that the likelihood of their occurrence depends mainly on tissue density, and the scattered X-rays produced in Compton collisions have a high probability of escaping from the patient and crossing the image plane.

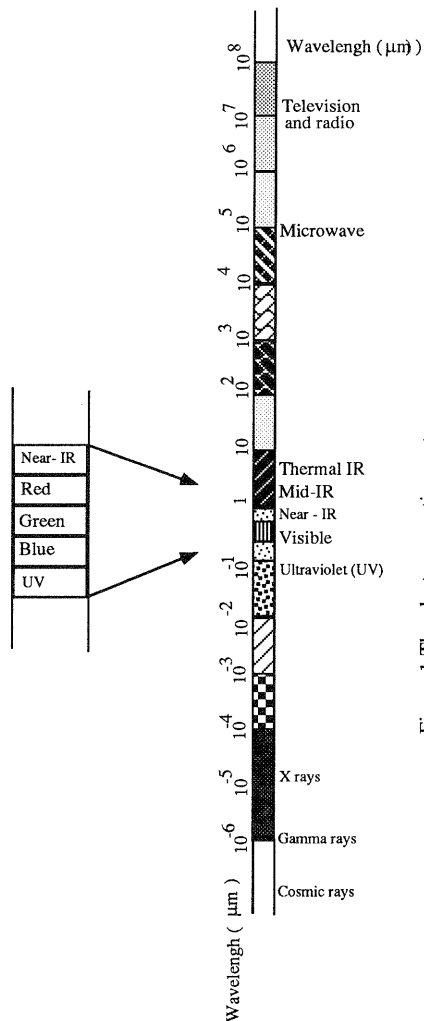


Figure 1. The electromagnetic spectrum, X rays range from  $10^{-4}$  to  $10^{-6}$  (  $\mu\text{m}$  )

Because their directions are unrelated to the position of the focal spot, these scattered X-rays do not carry any useful information about the patient and serve only to reduce X-ray contrast. Unfortunately, the interaction of diagnostic X-rays with soft tissue is mainly by the Compton process, and specific stratagems must be employed to prevent "scatter" from reaching the imaging device. The X-ray image is determined by the intensity distribution in the X-ray beam as it emerges from the patient. The quality, i.e. visibility and recognizability of the X-ray image, depends upon the focal-spot size, the incident X-ray spectrum, and the composition of the patient. Over many years the optimum parameters for a specific examination (e.g. X-ray tube potential, beam filtration, exposure time, infection of contrast media) have been empirically determined by a large number of practitioners.

At average diagnostic kilovoltage levels, about 5% or less of the primary radiation traverses completely through the patient's body, without interacting with any of the atoms in the patient, and strikes the film. In addition, about 15% of the primary radiation interacts with atoms resulting in the production of the secondary photons which make it out of the patient and strike the film. The remaining 80% of the primary beam is totally absorbed within the patient. Figure 2 illustrates the attenuation of an X-ray beam by the various tissues within the patient, resulting in a variation of transmitted radiation. The pattern of transmitted radiation

may be expressed in terms of variations in photon fluency, variations in energy fluency or variations in exposure.

X-ray images are formed in a manner similar to the regular black and white pictures. Body parts which have higher resistances to X-ray penetration ( bones ) result in less light reaching the film, and consequently brighter image on the X-ray transparency which is nothing more than a negative image. On the other hand, soft tissues have less resistance to X-rays, so more X-rays pass through them, resulting in more radiation reaching the film and producing darker tone. In most cases the bones are the brightest and gases are the darkest.

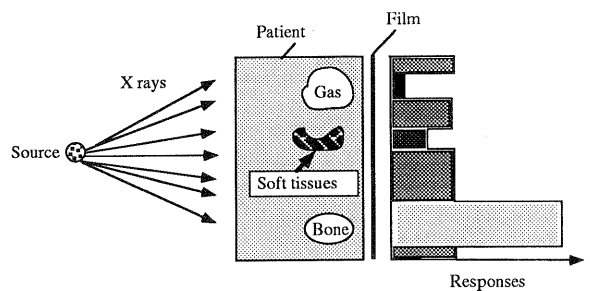


Figure 2. Formation of radiological image

### THE REJECTED X-RAY PICTURES

Rejected X-ray pictures are the ones which do not satisfy the initial intended purpose. They are usually thrown away or destroyed, and the radiographs have to be retaken. X-ray images may be rejected for more than one reason, for example: over or under exposure, patient movement, poor film development, and other causes which result in poor contrast. (Figures 3 and 4 show examples of rejected X-ray images.)

Rejected images account for 15 to 20 percent of the X-rays taken per year. This in turn costs public and private hospitals and clinics millions of dollars and exposes patients to unnecessary radiation which is a major public concern. They also slow down the diagnostic process and increase the cost which is passed on to the patients. Presently, the only solution radiologists and physicians offer is to destroy X-rays and take new ones. This has been and probably will be, the trend for the next decade. With the growing public concern of insurance cost, and with increase in computer capabilities both in software and hardware, the medical community have to find a better and more reasonable solution.

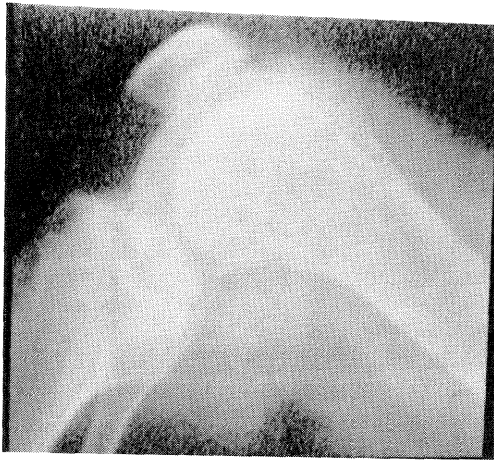


Figure 3. A rejected over exposed X-ray

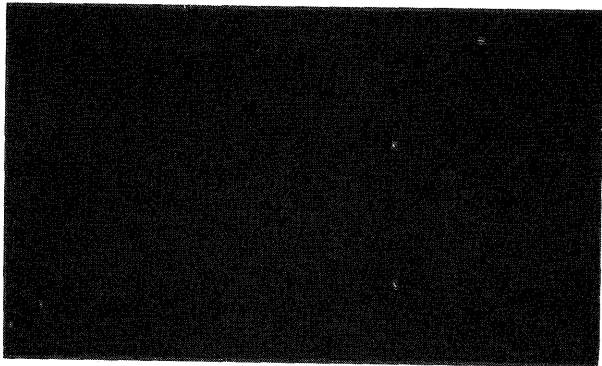


Figure 4. A rejected under exposed X-ray

### THE PROPOSED SYSTEM

Following is one possible solution to minimize the number of the rejected X-rays. The heart of the solution is the concept of image processing. All X-rays can be converted to digital images by simple or advanced scanning techniques. Once a digitized X-ray is obtained basic and advanced image processing techniques can be applied to it.

Research shows that more than 90% of the rejected images are due to over- or under-exposure or to poor contrast in the obtained radiographs. Less than 10% of the X-rays are rejected because of the patient moving. In these cases image restoration and enhancements can be applied to minimize and/or correct the problem.

The proposed system (figure 5) is nothing more than a typical image processing unit connected to an X-ray machine.

Six rejected X-ray pictures were selected and then were digitized at different resolutions ranging from 50 to 300  $\mu\text{m}$  pixel size. Initial statistics were collected to select proper restoration techniques. Spectral and spatial image enhancement techniques were applied to the digital image.

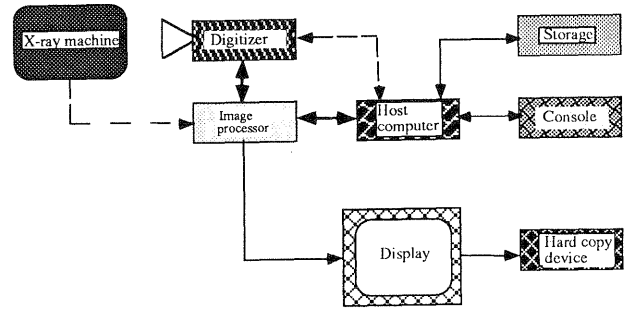


Figure 5. The Proposed System

Results show that linear and non-linear contrast enhancements increased the visual quality of the images and in many cases the new image is no longer classified as a rejected X-ray. Spatial enhancement has the effect of bringing up the details of the image. Logarithmic and exponential histogram equalization gave good results in most cases. A combination of linear stretch and histogram equalization also proved to be effective enhancement

techniques. High boost filter with central kernel value less than 10 gave the best result in most cases. High-frequency emphasis filter also proved to be a powerful tool for spatial enhancements. Different edge enhancement filters were examined and directional and Sobel filter worked the best. Figures 6, 7, 8 and 9 show some of the obtained results.

These figures demonstrates that indeed a good part of the rejected X-rays can be retrieved. This process not only reduces number of rejected X-rays, but it also increases the quality of both the rejected and the good X-rays. The new obtained X-ray is sharper and more visually interpretable. The procedure will save both patient and physician time and money and will be much safer than the present day system.

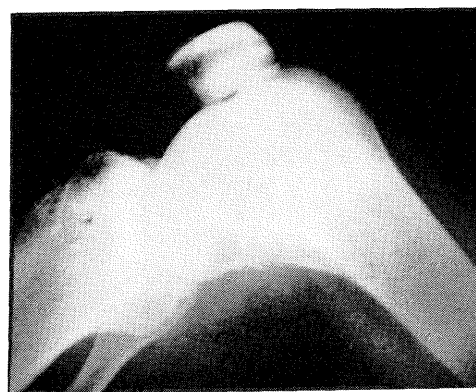


Figure 6. Exponential equalization for the X-ray in figure 3

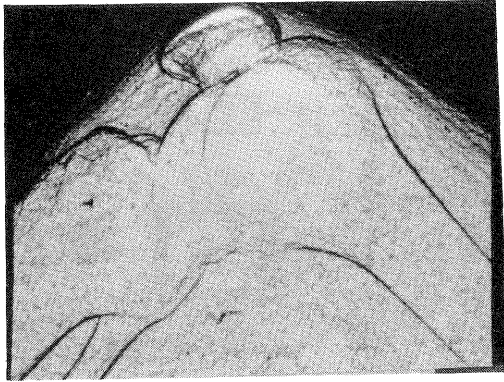


Figure 7. Sobel filter for the X-ray in figure 3

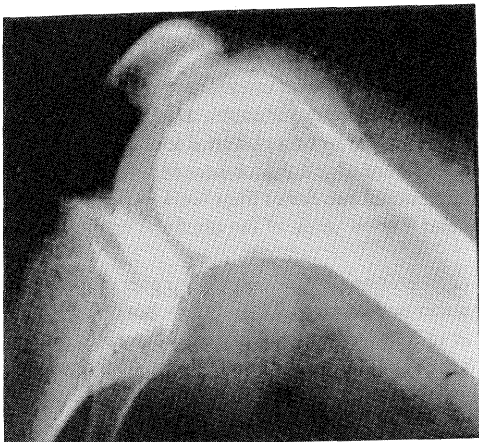


Figure 8. Simple histogram equalization of the X-ray in figure 4

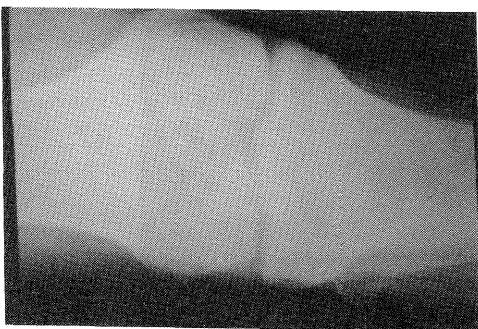


Figure 9-A. A rejected over exposed joint

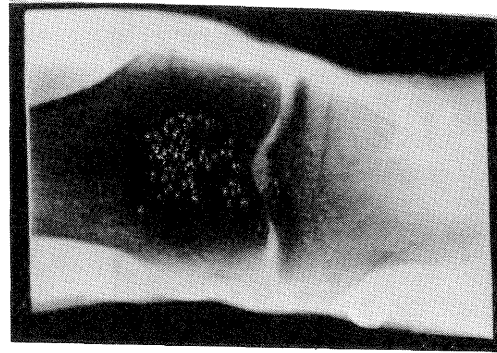


Figure 9-B. Exponential equalization for the X-ray in 9-A, notice the lighter tone in the middle of the joint

### Limitations and Practical Difficulties

This system would produce the expected result by minimizing the number of rejected X-ray pictures. However, several practical limitations should be addressed:

#### Resolution

The current X-ray film capture data and provide excellent resolution. Converting X-ray pictures from pictorial to digital would require the use of certain type of scanner. Currently there are many scanners in the market ranging from several hundred dollars to hundreds of thousands of dollars. Resolution and image quality obtained from these scanners increases with the prices. A scanner with 300 DPI might cost less than a thousand dollars, but the quality of the obtained image is not suitable for medical diagnosis. On the other hand, the quality of images scanned with 1200 DPI would be much higher and provide reasonable resolution for medical diagnosis, but it is much more expensive

Independent of scanner, the screen resolution for most commercially available monitors is 1024 X 1024. Therefore, if an image is scanned with 1200 DPI, and displayed on a 1024 X 1024 screen, the resolution will be less.

#### Size of Data Involved

Independent of scanner and monitor types, the obtained digitized image would require significant dynamic and static storage space. For example, a 15 X 16 inch chest X-ray digitized at 300 DPI would produce an image 4500 X 4800 pixels. This would need 22 megabytes of memory space. High quality digital image (1200 DPI) would require 345 megabytes. Any enhancement or restoration operations would require additional space.

#### Time

Currently it takes two minutes to obtain an X-ray image. This time includes taking the picture and developing the film. In the proposed system, the X-ray would be taken, would be digitized, and then processed. This would require additional time especially if a high quality image is

needed, which would make the system less efficient to the existing one.

Replacement of the film with electronic detectors would eliminate the digitization phase and increase the system efficiency but also increase the cost.

#### Attitude

Many radiologists and physicians are resisting any attempts to computerize conventional X-ray images. They view it as an unnecessary development process and see the existing system as the best that can be obtained with current technology.

All the above limitations will be reduced, and probably will become insignificant, as development of computer hardware and software advances. At that point, the negative attitude of the medical community will also be lessened and eventually digital X-ray would become a reality.

#### Conclusion

Image processing techniques can be used to minimize significantly the number of rejected X-rays. Enhanced image contrast and visibility will help both physicians and radiologists make more accurate diagnosis. This in turn will reduce the risk of radiation exposure and increase the economical benefits. The enhanced X-ray images are sharper, more visible and recognizable, and provide more information.

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