



Magnetic Resonance and Imaging, Processing and allied Technologies

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ABSTRACT: Image Processing is the novel ,burning technology in the digital world and has successfully rooted itself as the sole building brick of the modern techno-globe. It has cast an ever-lasting impression in the vital area of biomedical sciences in the form of Magnetic Resonance and Imaging (MRI) which has surpassed other conventional technologies. In our papyrus script , we have extended. the scope of this study in allied fields like fMRI, iMRI etc., and their growing momentous importance. Hoping that our attempts shall be a guiding milestone to satisfy the subject enthusiasts .

KEYWORDS: Magnetic Resonance Imaging (MRI), Image Processing, Medical Imaging, Signal Processing, Radiology, Biomedical Engineering, Computer-Aided Diagnosis

I. WHAT IS DIGITAL IMAGE PROCESSING?

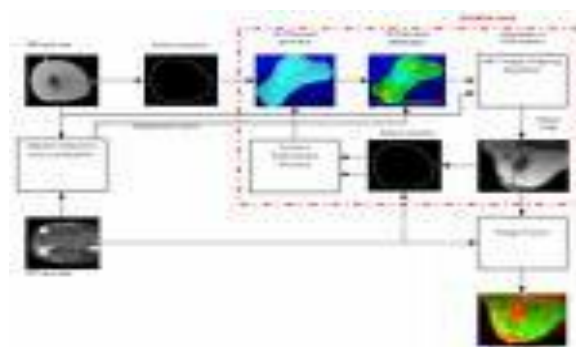
Digital image processing is the use of computer algorithms to perform image processing on digital images. Digital image processing has the same advantages over analog image processing as **digital signal processing** has over analog signal processing —it allows a much wider range of algorithms to be applied to the input data, and can avoid problems such as the build-up of noise and signal distortion during processing.

The term digital image processing refers to processing of a 2D picture by a digital computer. In a broader contest it implies digital processing of any 2D data.

Applications of Digital Image Processing:

Image processing is one of the emerging and promising field which finds many applications in diverse fields. These include

- Remote sensing via satellite and other spacecrafts
- Image transmission and storage for business applications
- Medical processing
- RADAR,SONAR, and other acoustic image processing
- Robotics
- Automated inspection of industrial parts





Images acquired by satellites are useful in tracking earth's resources; Geographical mapping; Predicting food crops, urban growth and weather; flood and fire control; and many other environmental applications. Space image applications include recognition and analysis of objects in images from deep space probe missions. It also finds application in broadcast tv, teleconferencing and transmission of fax images. In medical application it involves processing of chest x-rays, cineangiograms and other medical images that occur in radiology, nuclear magnetic resonance and ultrasonic scanning.

II. WHAT IS MRI?

Magnetic resonance imaging (MRI) is the newest, and perhaps most versatile, medical imaging technology available. Doctors can get highly refined images of the body's interior without surgery, using MRI. By using strong magnets and pulses of radio waves to manipulate the natural magnetic properties in the body, this technique makes better images of organs and soft tissues than those of other scanning technologies. MRI is particularly useful for imaging the brain and spine, as well as the soft tissues of joints and the interior structure of bones. The entire body is visible to the technique, which poses few known health risks.

MRI is a way of getting pictures of various parts of your body *without* the use of x-rays, unlike regular x-rays pictures and CAT scans. A MRI scanner consists of a large and very strong magnet in which the patient lies. A radio wave antenna is used to send signals* to the body and then receive signals back. These returning signals are converted into pictures by a computer attached to the scanner. Pictures of almost any part of your body can be obtained at almost any particular angle.

MRI : A cutting edge over other types of conventional scans

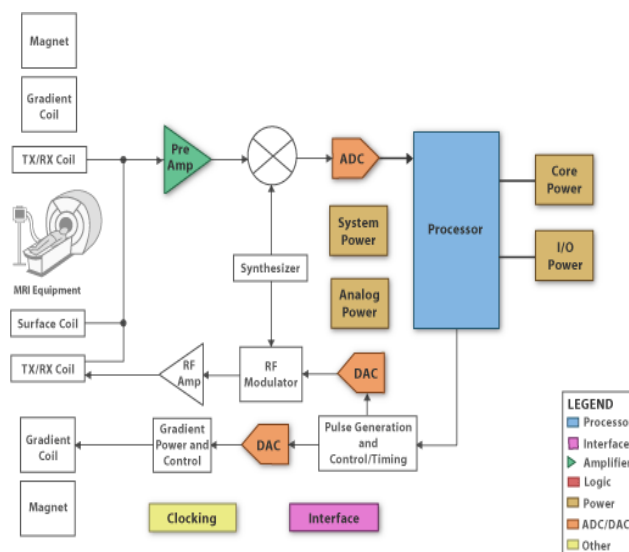
MRI scanners are good at looking at the non-bony parts or "soft tissues" of the body. In particular, the brain, spinal cord and nerves are seen much more clearly with MRI than with regular x-rays and CAT scans. Also, muscles, ligaments and tendons are seen quite well so that MRI scans are commonly used to look at knees and shoulders following injuries. A MRI scanner uses no x-rays or other radiation.

The advantages of MRI over CT scans are:

- They do not use X-rays.
- They can scan in any plane.
- They show the pituitary with superior resolution.
- The injection is less likely to cause an allergic reaction (it contains gadolinium).

Working of MRI:

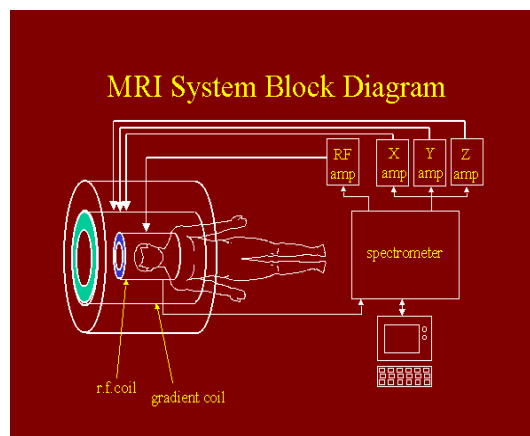
The working of an MRI can be depicted as below :



Product Availability and Design Disclaimer - The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability



Magnetic Resonance Imaging (MRI) is a non-invasive diagnostic technology that produces physiologic images based on the use of magnetic and radio frequency (RF) fields. The MRI system uses powerful magnets to create a magnetic field which forces hydrogen atoms in the body into a particular alignment (resonance). Radio frequency energy is then distributed over the patient, which is disrupted by body tissue. The disruptions correspond to varying return signals which, when processed, create the image. The accurate processing of these signals is key to obtaining high quality images. A key system consideration for the receive channel is high SNR. The return signals have narrow bandwidths with an IF location directly dependent on the main magnet's strength. Some systems use high-speed pipeline ADCs with wideband amplifiers to directly sample the IF, leaving large headroom for post-processing gain by a digital down converter or FPGA. Other systems mix the IF to baseband where lower-speed, higher-resolution SAR and delta-sigma ADCs can be used. For controlling the magnetic and RF energy in the MRI, high-resolution, high-speed DACs are needed. High resolution is required to accurately define the area of the patient to be scanned. High-speed is necessary to match the high IFs being generated by the main magnet. DSPs can be used to provide gradient processor control used for properly controlling the magnets in the MRI system. A DSP can also take care of preprocessing the signal before it reaches the image reconstruction engine. The **cube** in a typical system might be 7 feet tall by 7 feet wide by 10 feet long (2 m by 2 m by 3 m), although new models are rapidly shrinking. There is a **horizontal tube** running through the **magnet** from front to back. This tube is known as the **bore** of the magnet. The patient, lying on his or her back, slides into the bore on a special table. Whether or not the patient goes in head first or feet first, as well as how far in the magnet they will go, is determined by the type of exam to be performed. Once the body part to be scanned is in the exact center or **isocenter** of the magnetic field, the scan can begin.



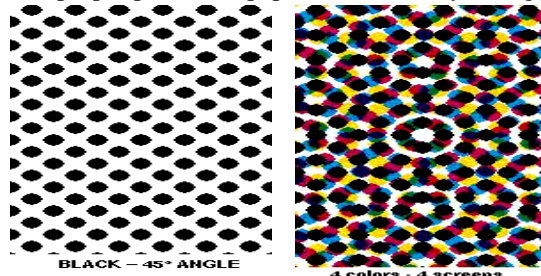
Modern 3 Tesla clinical MRI scanner

The CMYK color scheme : Basis of MRI display

Unlike the other simulation methods which employ RGB, or gray level schemes for image representation, here Cyan-Magenta-Yellow-Black scheme is adopted for visual representation of the images. When these four inks (collectively



known as CMYK) are combined, they can produce millions of different colors. In process printing on paper, a 50% screen of any color would be represented as a dot pattern which visually occupies 50% of the paper surface. When screens of the four colors are combined in a proper pattern on paper, the human eye merges them into one color.



Also called **REFLECTIVE** or **SUBTRACTIVE** colors, process inks filter light as it is reflected off the paper, allowing only certain wavelengths of light to reach our eyes. By adjusting the amount of any ink on the paper, the reflected wavelength changes, changing the color we see.

MRI vs CT : viz – a –viz.

A computed tomography (CT) scanner uses X-rays, a type of ionizing radiation, to acquire its images, making it a good tool for examining tissue composed of elements of a relatively higher atomic number than the tissue surrounding them, such as bone and calcifications (calcium based) within the body (carbon based flesh), or of structures (vessels, bowel). MRI, on the other hand, uses non-ionizing radio frequency (RF) signals to acquire its images and is best suited for non-calcified tissue.

CT may be enhanced by use of contrast agents containing elements of a higher atomic number than the surrounding flesh such as iodine or barium. Contrast agents for MRI are those which have paramagnetic properties. One example is gadolinium.

Both CT and MRI scanners can generate multiple two-dimensional cross-sections (slices) of tissue and three-dimensional reconstructions. Unlike CT, which uses only X-ray attenuation to generate image contrast, MRI has a long list of properties that may be used to generate image contrast. By variation of scanning parameters, tissue contrast can be altered and enhanced in various ways to detect different features. MRI can generate cross-sectional images in any plane (including oblique planes). CT was limited to acquiring images in the axial (or near axial) plane in the past. The scans used to be called Computed Axial Tomography scans (CAT scans). However, the development of multi-detector CT scanners with near-isotropic resolution, allows the CT scanner to produce data that can be retrospectively reconstructed in any plane with minimal loss of image quality.

For purposes of tumor detection and identification, MRI is generally superior. However, CT usually is more widely available, faster, much less expensive, and may be less likely to require the person to be sedated or anesthetized. MRI is also best suited for cases when a patient is to undergo the exam several times successively in the short term, because, unlike CT, it does not expose the patient to the hazards of ionizing radiation.





III. UPS AND DOWNS OF MRI: A CRITICAL ANALYSIS

Lets reconcile as to why would our doctor order an MRI? Because the only way to see inside your body any better is to cut you open. MRI is ideal for:

- Diagnosing **multiple sclerosis** (MS)
- Diagnosing **tumors** of the pituitary gland and brain
- Diagnosing **infections** in the brain, spine or joints
- Visualizing **torn ligaments** in the wrist, knee and ankle
- Visualizing **shoulder injuries**
- Diagnosing **tendonitis**
- Evaluating **masses** in the soft tissues of the body
- Evaluating **bone tumors, cysts** and **bulging or herniated discs** in the spine
- Diagnosing **strokes** in their earliest stages

These are but a few of the many of reasons to perform an MRI scan.

The fact that MRI systems do not use ionizing radiation is a comfort to many patients, as is the fact that MRI contrast materials have a very low incidence of **side effects**. Another major advantage of MRI is its ability to image in **any plane**. CT is limited to one plane, the axial plane (in the loaf-of-bread analogy, the axial plane would be how a loaf of bread is normally sliced). An MRI system can create **axial images** as well as images in the **sagittal plane** (slicing the bread side-to-side lengthwise) and **coronally** (think of the layers of a layer cake) or any degree in between, without the patient ever moving. If you have ever had an X-ray, you know that every time they take a different picture, you have to move. The three gradient magnets discussed earlier allow the MRI system to choose exactly where in the body to acquire an image and how the slices are oriented.

On the other hand, this technique poses some serious issues. Although MRI scans are ideal for diagnosing and evaluating a number of conditions, it does have drawbacks. For example:

- There are many people who cannot safely be scanned with MRI (for example, because they have **pacemakers**), and also people who are **too big** to be scanned.
- There are many **claustrophobic** people in the world, and being in an MRI machine can be a very unpleasant experience for them.
- The machine makes a tremendous amount of **noise** during a scan. The noise sounds like a continual, rapid hammering. Patients are given earplugs or stereo headphones to muffle the noise (in most MRI centers you can even bring your own cassette or CD to listen to). The noise is due to the rising electrical current in the wires of the gradient magnets being opposed by the main magnetic field.
- MRI scans require patients to **hold very still** for extended periods of time. MRI exams can range in length from 20 minutes to 90 minutes or more. Even very slight movement of the part being scanned can cause very distorted images that will have to be repeated.
- Orthopedic hardware (screws, plates, artificial joints) in the area of a scan can cause severe **artifacts** (distortions) on the images. The hardware causes a significant alteration in the main magnetic field.

MRI systems are very, very **expensive** to purchase, and therefore the exams are also very expensive.

Scope of MRI :

The future of MRI seems limited only by our imagination. This technology is still in its infancy, to say on comparative terms. Very **small scanners** for imaging specific body parts are being developed. For instance, a scanner that you simply place your arm, knee or foot in are currently in use in some areas. Our ability to visualize the arterial and venous system is improving all the time. Functional **brain mapping** (scanning a person's brain while he or she is performing a certain physical task such as squeezing a ball, or looking at a particular type of picture) is helping researchers better understand how the brain works. The development of new, improved ways to image strokes in their earliest stages is ongoing.

Predicting the future of MRI is speculative at best, but there is no doubt that it will be exciting for those in the field, and very beneficial to the patients who need care .

The Future Role of functional MRI in Medical Applications

The recent discovery that MRI can be used to map changes in brain hemodynamics that correspond to mental operations extends traditional anatomical imaging to include maps of human brain function. The ability to observe both the structures and also which structures participate in specific functions is due to a new technique called **functional**



magnetic resonance imaging, fMRI, and provides **high resolution, noninvasive reports of neural activity** detected by a blood oxygen level dependent signal. This new ability to directly observe brain function opens an array of new opportunities to advance our understanding of brain organization, as well as a potential new standard for assessing neurological status and neurosurgical risk.

What is fMRI ?

Functional MRI is based on the increase in blood flow to the local musculature that accompanies neural activity in the brain.. Using an appropriate imaging sequence, human cortical functions can be observed without the use of exogenous contrast enhancing agents on a clinical strength (1.5 T)

The main advantages to fMRI as a technique to image brain activity related to a specific task or sensory process include :

- ➔ the signal does not require injections of radioactive isotopes,
- ➔ the total scan time required can be very short, i.e., on the order of 1.5 to 2.0 min per run (depending on the paradigm), and
- ➔ the in-plane resolution of the functional image is generally about 1.5 x 1.5 mm although resolutions less than 1 mm are possible.

To put these advantages in reality, functional images obtained by the earlier method of **positron emission tomography, PET**, require injections of radioactive isotopes, multiple acquisitions, and, therefore, extended imaging times. Further, the expected resolution of PET images is much larger than the usual fMRI pixel size..

Methods and Procedures

The particular imaging methods and procedures vary because each group has independently developed the methods and analysis procedures required to acquire and process functional data. The five clinical techniques described below, serves to illustrate the general conditions of fMRI:

- **Image Acquisition:** Images are acquired using a T2* weighted gradient echo sequence: Each imaging series requires approximately 30 complete head volume acquisitions.
- **Image Processing:** This facility provides the computational capability required to reconstruct the large numbers of images and provides the statistical analyses that identify the anatomical regions that are active during specific tasks.
- **Task Procedure:** Patients and subjects are positioned in the scanner as for a conventional scan, and plane lines are set based on conventional imaging methods.. A task-induced signal change is illustrated in Fig. 1 for a sensory task involving tactile stimulation (touching) the left hand. The abscissa represents a 30 image acquisition run during a 90 sec period. The initial 10 pre-stimulation (baseline) images are followed by 10 activation images (left hand stimulation) and 10 post-stimulation images. Each 90 sec imaging series (illustrated by the intensity levels for one voxel) is actually repeated twice although only one series is illustrated. In this example the left hand stimulation results in right hemisphere activity and presumably represents the post central sulcus sensory strip. Fig.1
- **DataData analysis:** Statistical analyses have been developed to identify areas of the brain activated by specific tasks and are based on a multistage comparison of stimulation and resting intensity levels as well as multiple replications indicate the in-plane location and z indicates the slice. Significant voxels (as shown in Fig. 1) indicate regions of the brain activated by a specific task. . Voxels that do not show a significant intensity change during the activity period are not colored. Rather, they are represented by the mean level which yields the anatomic detail for each slice of brain.

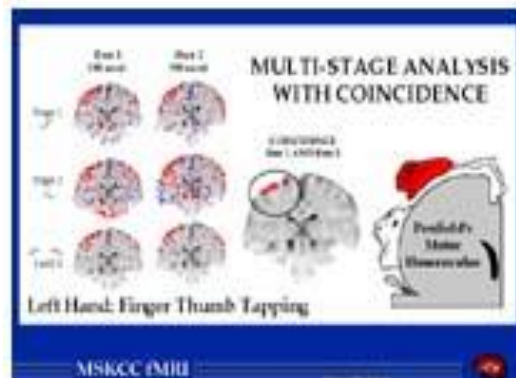




IMAGE – GUIDED SURGERY : A Novel Approach

Most MRI centers require an orbital x-ray be performed on anyone who suspects they may have small metal fragments in their eyes, perhaps from a previous accident, something not uncommon in metalworking.

Because of its non-ferromagnetic nature and poor electrical conductivity, titanium and its alloys are useful for long term implants and surgical instruments intended for use in **image-guided surgery**. In particular, not only is titanium safe from movement from the magnetic field, but artifacts around the implant are less frequent and less severe than with more ferromagnetic materials e.g. stainless steel. Artifacts from metal frequently appear as regions of empty space around the implant - frequently called 'black-hole artifact' e.g. a 3mm titanium alloy coronary stent may appear as a 5mm diameter region of empty space on MRI, whereas around a stainless steel stent, the artifact may extend for 10-20 mm or more.

Future Role in Pain Management

This novel approach to investigate the cortical representation associated with relief of pain has originated from our pilot studies where patients with chronic sympathetically maintained pain affecting one extremity were studied by comparing brain responses to light touch applied to the "now-affected" limb and to the "painful" limb before and after treatment. These studies indicate that the cortical representation of sympathetically maintained pain involves specific and identifiable cortical activity, as well as does the relief of that pain achieved by a peripheral nerve block procedure.

Future role in understanding the physiological basis for Neurological Disorders

The following example illustrates the potential of fMRI to yield new insights into physiological bases for dysfunction. One of the patient's typical sensory seizures occurred during one of the runs. This enabled us to localize fMRI signals associated with the onset of a spontaneous seizure, its progression, and the relationship to normally activated motor cortex. The fMRI signals associated with the seizure were first observed in an area adjacent to the normal motor activity. MR signal amplitudes exceeded the normal functional activity by as much as a factor of 5. The eloquent motor activity and seizure activity were co-localized using fMRI, and the onset, progression pattern, time course, and relative MR amplitudes of the seizure event were observed.

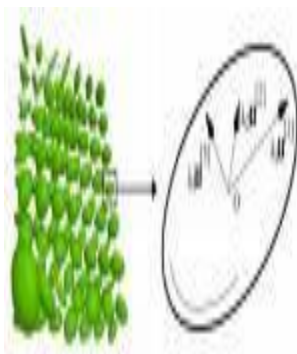
Preliminary studies confirm that the pathways and processes involved in these neurological disorders and conditions can be observed for investigation by fMRI.

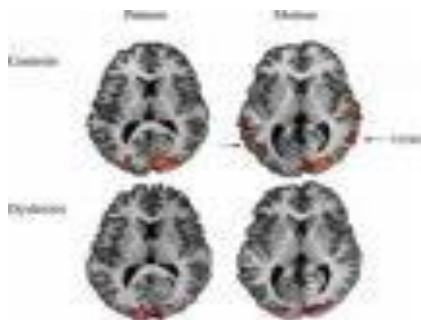
Future role in understanding the physiological basis for cognitive and perceptual events

Due to the ability to image the entire 3-dimensional volume of brain, fMRI is capable of isolating many simultaneous and coordinated brain events. This "multi-level" view of brain activity can include "executive" functions and high level cognitive tasks simultaneously with the primary and secondary input such as vision and audition as well as cerebellar contributions. At present, fMRI methods are being applied to identify brain structures uniquely involved with visual perceptions, language generation, comprehension of sequential information as in a movie, the execution of visually guided responses, and complex problem solving. These aspects of brain function have not previously been scrutinized with such precision, and represent some of the remaining frontiers in Neuroscience.

Future Decisions

Based on the initial investigations, the future directions include neurosurgical planning and improved assessment of risk for individual patients, improved assessment and strategies for the treatment of chronic pain, improved seizure localization, and improved understanding of the physiology of neurological disorders. According to an American bio medical image processing lab, it is estimated that by 2013, fMRI will be extended for all bodily part analysis and clear results would be obtained due to rapid advancement in this technology.





IV. CONCLUSION

Image Processing is one of the most fascinating, emerging and lucrative areas of the computing scenarios. Far fledged applications are simply indispensable and have altogether opened a new avenue to be explored. This paper, it has been our meagre attempt to give the readers a flavor of its role in biomedical technology in the form of Magnetic Resonance and Imaging. We express our heartfelt gratitude for allowing us to share our thoughts for **Knowledge swells when spreads !!** We hope that this paper turns about to be a stepping stone for your journey in this new arena and proves to be a handy aid for the image processing enthusiasts.

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