Data Acquisition Modalities

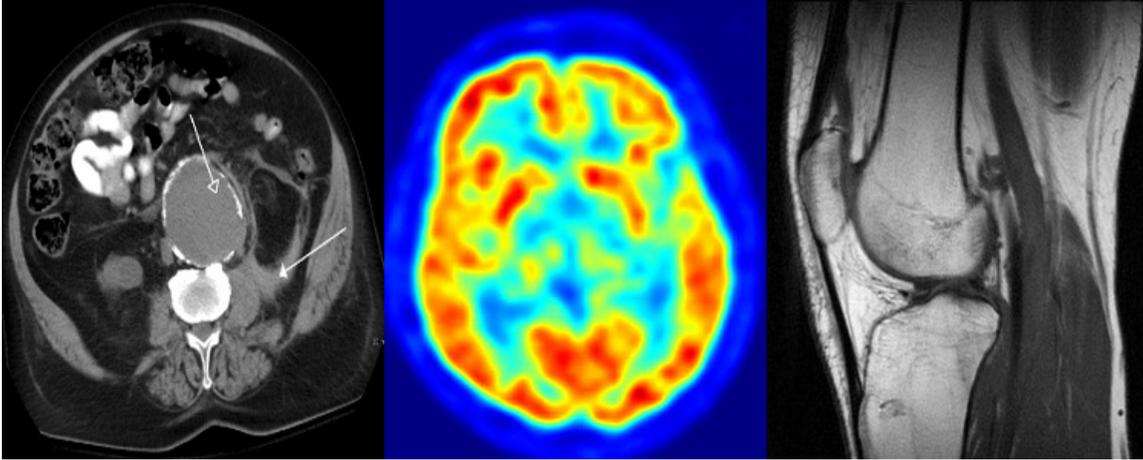Vedran Omeragic*
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Figure 1: Different types of data acquisition modalities in medical imaging. From left to right: computed tomography (CT), positron emission tomography (PET) and magnetic resonance imaging (MRI). Courtesy of Wikipedia. [Wikipedia 2011h]

Abstract

The development in technology in the past few decades brought revolutionary changes and significant advancements to the techniques of medical imaging. At the heart of every medical imaging modality is a sophisticated mathematical model of the measurement process, as well as the algorithms to reconstruct an image from the measured data. This paper will focus on introducing data acquisition in such techniques, their process, advantages, limitations, as well as their short history.

Keywords: medical imaging, data acquisition, image processing, tomography, magnetic resonance, ultrasound, nuclear medicine

1 Introduction

Medical imaging describes a process of acquiring an image of the human body or parts of it for either clinical purposes or medical science [Branstetter 2007]. As a scientific method it is a part of biological imaging and incorporates a wide set of techniques, such as radiology, nuclear imaging, endoscopy, medical thermography and photography, microscopy and many more. For example, three dimensional volumetric visualization of MRI data of internal organs has become a standard for routine patient diagnostic care.

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According to Basics of Imagig informatics [Branstetter 2007] non-invasive procedures are used to designate a set if imaging techniques, which produce images of the internal aspects of the body. In short, noninvasive is a term based on a fact that these imagining technique do not penetrate the skin physically. However, on the atomic levels they are very invasive. From high energy photons of X-ray to the Tesla coils of an magnetic resonance imaging machine, these modalities alter physical and chemical environment of the body in order to obtain certain data. In computed tomography for example, the denser tissues such as bones, absorb more X-rays and show as light areas on X-ray film. Furthermore, a contrast medium can be used to highlight soft tissues in X-ray pictures or can be followed on X-ray films as it moves through the body to record bodily processes.

The discovery of magnetic resonance, ultrasound, radioactivity and X-rays, as well as the development of imaging instruments, proved to be one of the most effective diagnostic tools. Today we are able to probe into a structure and function of the human body using a number of imaging systems, which are further used to plan treatment and surgery of patients. Use of such technology is not limited only to clinical purposes. For example, computed tomography is often used in industry to detect flaws of products. Data sets in two or three dimensions convey a vast array of information for clinical or research applications. This information, however, needs to be interpreted in a timely and accurate manner for it to be usable [Branstetter 2007]. In order to visually interpret images, the international imaging community developed numerous techniques, each with advantages, limitations and field of application.

The advancements in medical imaging require a significant innovations in computational techniques. The use of multiple modalities on a single patient requires sophisticated algorithms for image registration and pattern matching. Automated recognition and diagnosis require image segmentation, quantification and enhancement tools. The widespread availability of imaging requires efficient and effective image compression and communication methods.

1.1 Data Acquisition

Medical imaging is an interdisciplinary subject that requires understanding of physics, technology, and practice of each medical imaging modality. In order to explain the basics of imaging process it is imperative to first understand the term data acquisition. Such process describes a way of sampling signals in an analog waveforms, which measure real world physical conditions and then convert them into digital values, which can further be analyzed and manipulated by a computer. Data acquisition systems, hereafter referred to as DAQ, consist of three components [Wikipedia 2011g]:

- Sensors (convert physical parameters to electrical signals).

- Signal conditioning circuitry (convert sensor signals into a conditioned form, which can further be used to converted to digital values).

- Analog-to-digital converters (convert conditioned signals to digital values).

Next step requires a software component, usually developed by a general purpose programming languages such as BASIC, C, Fortran, Java List, Pascal and graphical programming environments which include Visual Basic, Visual C++ and Ladder logic [Wikipedia 2011g].

1.1.1 Methodology

The process of acquisition begins once physical phenomenon which needs to be measured occurs. For example light intensity, temperature or pressure. Their physical state is then measured, transformed into a unified form, which can later be read by a DAQ. This task is performed by a device called sensor, a type of transducer (device which converts one type of energy to another) [Wikipedia 2011g]. A sensor converts a physical property into a corresponding electrical signal, e.g. voltage. Different types of sensors have different application fields, each with the ability to measure different physical properties and states.

Depending on used transducer, signals can be either analog or digital. Some signals need to be conditioned first [Wikipedia 2011g] if the signal form from transducer is not suitable for a specific DAQ hardware. The signal my need to be amplified, filtered or demodulated. For transmission purposes single ended analog signals, which are more susceptible to noise, can be converted to the differential signals. Once digitized, the signal can be encoded to reduce and correct transmission errors.

DAQ hardware represents an interface between the signal and a PC [Wikipedia 2011g]. It could be in the form of modules that can be connected to the computers ports or cards which can be connected to the corresponding slots. DAQ cards often contain multiple components like multiplexer, ADC, DAC, TTL-IO, high speed timers and RAM. Many times reconfigurable logic is used to achieve high speed for specific tasks. Digital signal processors are used after the data has been acquired to obtain some results. The fixed connection with the PC allows for comfortable compilation and debugging.

1.1.2 Modalities

Medical modalities produce representations of anatomical (structural) or molecular, physical and psychological (functional) information of a body part, or a body in whole. X-rays images for example, are representations of the distribution of linear attenuation coefficients of tissues and are usually images of anatomy or the struc-

tural nature of the tissues [Wikipedia 2011e]. On the other hand, radioisotope imaging (nuclear medicine) produces images of distributions of chemical, molecular or physiological function of the tissue. Other modalities like ultrasound can measure signal propagation or flow through vessels.

Modalities are characterized by the type of energy source they use, and can be separated in two groups [Wikipedia 2011g]:

- One group uses ionizing radiation and is an invasive technique, which produces energetic charged particles that penetrate a medium or an object where the energy is absorbed. This group counts radiography, fluoroscopy, mammography, computer tomography and nuclear medicine.

- Other group uses non-ionizing radiation, which is a non invasive technique and it counts ultrasound and magnetic resonance imaging.

1.1.3 Imaging types

Depending on the method of acquiring images, there are two types of imaging, planar and cross-sectional [Wikipedia 2011g].

In projection (planar) imaging X-rays pass through the object, which are then detected on the opposite side of the said object. As a result, a two-dimensional shadow representation of the tissues lying between the source and the detector is produced. Sometimes, overlapping layers of tissues can make planar imaging a bit difficult to interpret.
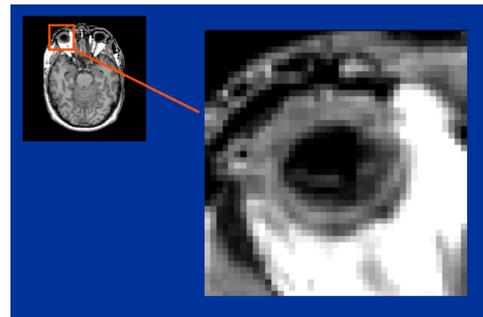

Figure 2: What exactly is an image? Processed image represents a two dimensional array of pixels.
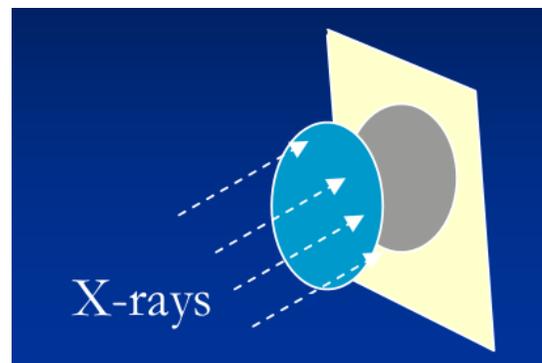

Figure 3: Planar imaging, showing X-rays penetrating the object and passing through it. Courtesy of Carver College of Medici, University of Iowa. [Ni 2009]
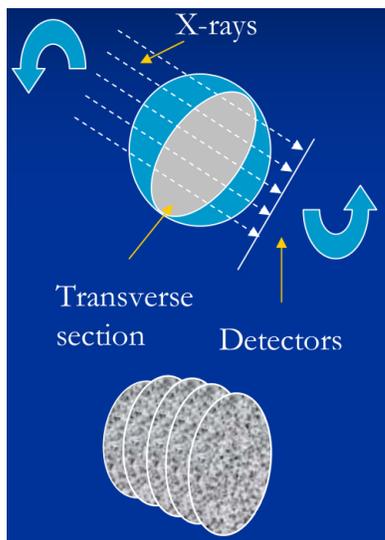
Figure 4: Cross-sectional imaging showing X-rays penetrating a transverse section of the object, while the source and detector rotate synchronously around the object. Courtesy of Carver College of Medicine, University of Iowa. [Ni 2009]

Tomographic (cross-sectional) imaging modalities include computer tomography, magnetic resonance imaging and ultrasound. The source and detectors rotate together around the object. The result is a large number of one-dimensional projections at a number of different angles, which are then mathematically reconstructed to make a two-dimensional image of a slice through the object.

1.1.4 From 2D to 3D

In order to reconstruct a 3D representation of the object, a set of 2D image slices taken around a single axis of rotation is required [Branstetter 2007]. Afterward, digital geometric processing is used to generate a three-dimensional image of the object. Historically, images have been generated in the axial (transverse) plane, which is orthogonal to the long axis of the body, but modern scanners can reformat the data in any orientation or as a volumetric representation.

2 Imaging technology

Imaging defines the ability to capture, storage, manipulation and display images [Wikipedia 2011g] . In medical imaging the emphasis lies on the ability to capture sensory data from various medical machine (e.g. medical resonance imaging scanners or computed tomography scanners) and convert the analog data into digital, making a usable image which can further be used for clinical purposes or medical research.

2.1 Computed tomography

Computed tomography(CT) or Computed axial tomography(CAT) is a medical imaging technique which uses tomography, which refers to imaging by sections through the use of any kind of penetrating waves [Wikipedia 2011e]. Later, digital geometry processing is used to create 3D representation of an object, using a large
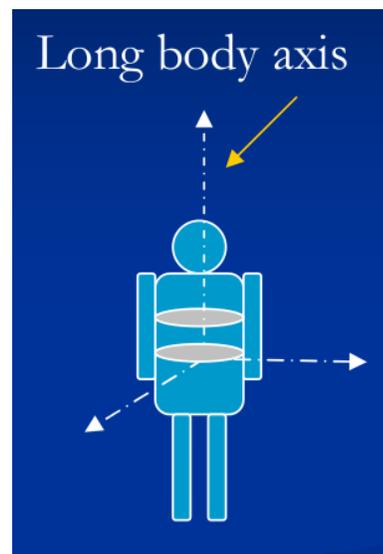

Figure 5: The object, a human in this example, which needs to be reconstructed in 3D. Long body axis represents an axis of rotation, around which source of energy and detectors rotate. Courtesy of Carver College of Medici, University of Iowa. [Ni 2009]

Figure 6: A patient receiving a CT scan for cancer. In the right corner is an imaging computer that reveals a 3D image of the body's interior. Courtesy of Wikipedia. [Wikipedia 2011c]

set of 2D X-ray images taken around a single axis of rotation of the mentioned object. CT employs a windowing technique in order to show different bodily structures based on their ability to reflect or absorb X-rays. In practice CT refers to a tomography from X-ray images, but sometimes the term computer tomography can also be used to describes positron emission topography (PET) or single photon emission computed tomography (SPECT), which belong to nuclear medicine.

2.1.1 Data acquisition

In order to generate X-ray slice of an object, a source of X-ray is placed on the opposite side of the detectors (sensors), with the object standing between them. Earliest versions of sensors were scintillation detectors with photomultiplier tubes excited by cesium iodide crystals. These crystals were later replaced by Xenon gas, while the photomultipliers were replaced by photodiodes [Branstetter 2009]. Newer machines, faster computers and more advance software allow processing of continuously changing cross sections.
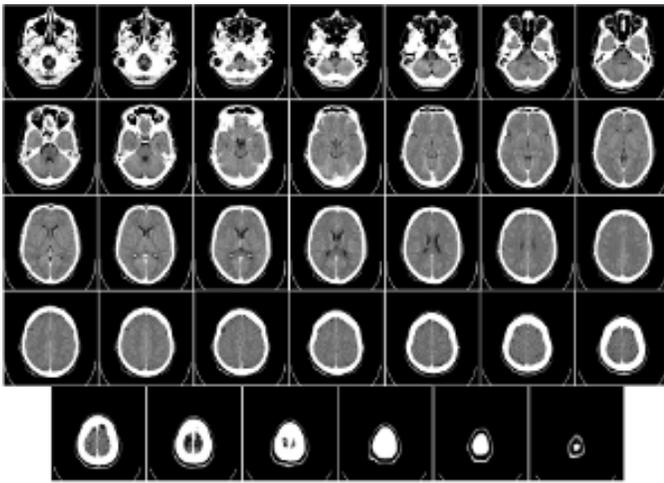
Figure 7: Computed tomography of human brain, from base of the skull to top. Intravenous contrast medium is used to enhacne the image. Courtesy of Wikipedia. [Wikipedia 2011d]

In conventional CT machines, an X-ray tube (a vacuum tube which produces X-rays) and detector are physically rotated in a circular motion around the imaged object.

2.1.2   Data processing and reconstruction

Once the sensory data is acquired it must be processed by tomographic reconstruction which produces a set of cross-sectional images [Wikipedia 2011e]. The projection of an object at a given angle is made up of a set of line integrals. In X-ray CT, the line integral represents the total attenuation of the beam of x-rays as it travels in a straight line through the object. The resulting image is a 2D or 3D model of the attenuation coefficient.

In theory an any image μ(x,y) can be found using the function known as the Radon transform (or sinogram) [Preim and Bartz 2007]. Data is collected as a series of parallel rays, at position r, across a projection at angle θ. This is repeated for various angles.

While Radon transform is most commonly used today, there are other techniques as well [Preim and Bartz 2007]. Linear algebra, for example, was used by early EMI scanners, but the it was very limited due to computational complexity and technical capabilities of that time. Recently, manufacturers have developed iterative physical model-based expectation-maximization techniques. The advantage of this technique lies in its ability to use internal model of scanner's physical properties and the laws of X-ray interactions, the result are images with improved resolution, reduced noise and fewer artifacts, as well as the ability to greatly reduce the radiation dose in certain circumstances. The disadvantage, however, is a very high computational requirement [Wikipedia 2011e].

The result of processing is an image consisting of pixels which individually display the relative radiodensity of one part of the tissue according to the mean attenuation of that tissue, which corresponds to values of Hounsfield scale (from the most attenuating 3071 to least attenuating -1024) [Branstetter 2007]. While a pixel is a two-dimensional unit, once CT slice thickness is factored in, it is then known as a Voxel [Wikipedia 2011e], a three-dimensional unit. The phenomenon in which a part of the detector cannot differentiate between different tissues is called the Partial Volume Effect. Some materials like steel iron, can completely extinguish the
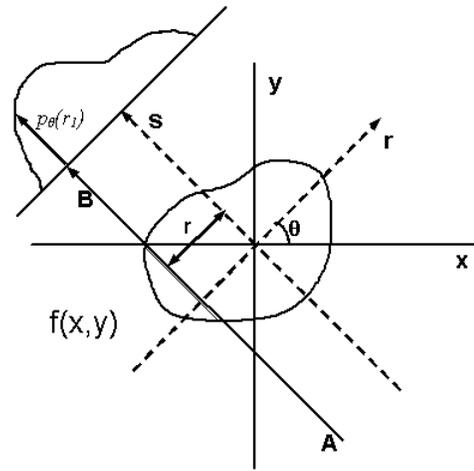

Figure 8: Parallel beam geometry. Each projection is made up of the set of line integrals through the object. The projection of an object at a given angle μ is made up of a set of line integrals. The line integral represents the total attenuation of the beam of x-rays as it travels in a straight line through the object. The resulting image is a 2D model of the attenuation coefficient. Courtesy of Wikipedia. [Wikipedia 2011k].

$$p(r,\theta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(x\cos\theta + y\sin\theta - r)\,dx\,dy$$

Figure 9: Radon transform, where searched image μ(x,y) is represented by f(x,y), x and y are the coordinates, θ is an angle and p is total attenuation of a beam at position r. Courtesy of Wikipedia. [Wikipedia 2011o]

X-rays, which causes line-artifacts. Such artifact are caused by abrupt transition from low and high density materials, causing values which exceed the technical limitations of processing electronics. Sometimes a contrast medium is used for CT to enhance the structural integrity of internal organs on the image. Such material is called radiocontrast and it is usually iodine-based.

Contemporary CT scanners offer isotropic or near isotropic resolution. Such display of images does not have to be restricted to the conventional axial images. With the use of a software program, it is possible to build a three-dimensional representation of the object by stacking individual slices on top of the other.

2.1.3   Field of application

Computed tomography is vastly used for diagnostic purposes to image patients head, lungs, abdomen, pelvic or extremities, and later use this data to diagnose the disorder. Other then just the medical application, industrial CT Scanning is a process which utilizes X-ray equipment to produce 3D representations of components. It has been utilized in many areas of industry for internal inspection of components. Some of the key uses for CT scanning have been flaw detection, failure analysis, meteorology, assembly analysis and reverse engineering applications. [Wikipedia 2011e]
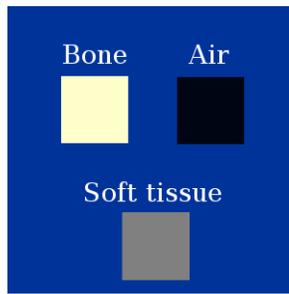
Figure 10: Three different pixels, showing the radiodensity of an object. Since every tissue absorbs X-Rays at different rates, some parts of the body will be showns as white (bones), shadowy gray (soft tissue like muscle) or black(air).
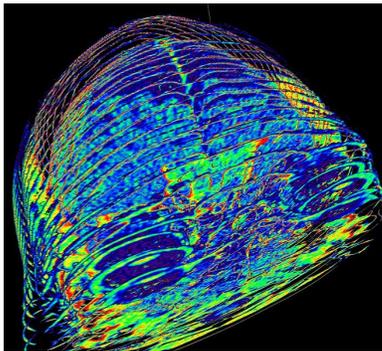

Figure 11: 3D reconstruction of the cranial CT. The 3D construction of the model is done by taking 2D images of the head and stacking them on top of each other. The result is the 3D model of the patients head. Since these are simply 2D images stacked up, when viewed on edge the slices disappear since they have effectively zero thickness. Courtesy of Wikipedia. [Wikipedia 2011b]

2.2   Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) or magnetic resonance tomography (MRT) is a noninvasive medical imaging technique used to visualize internal structures and unlike CT scans, MRI uses no ionizing radiation [Wikipedia 2011i]. MRI uses nuclear magnetic resonance to image nuclei of atoms inside the body. MRI machines creates a powerful magnetic field which aligns the magnetization of some atoms in the body and uses the radio frequency fields to alter the alignment. As the effect, the nuclei produce a rotating magnetic field detectable by scanners. This information is then recorded to construct the image of scanned area of the body. Stronger magnetic fields can cause nuclei at different locations to rotate at different speed and three-dimensional image can be constructed if gradient is provided in each direction. The 3DFT technique is similar to 2DFT except that there is no slice selection and phase-encoding is performed in two separate directions.

Objects with metal parts or with properties of metal are not allowed in MRI machines due to effects of the strong magnetic field and powerful radio frequency pulses [Branstetter 2007]. Once the magnetic field is turned on, a patient with a metal implant would have the implant ripped out of him by the strong magnetic force.

Figure 12: Magnetic Resonance Imaging Scanner. Courtesy of Wikipedia. [Exchange 2011]
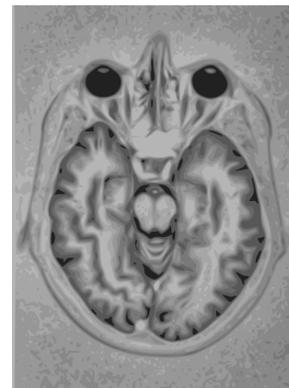

Figure 13: Representation of the brain in MRI. Courtesy of Wikipedia. [Wikipedia 2011j]

2.2.1   Data acquisition

When an object is placed inside the MRI machine, the powerful magnetic field aligns the magnetic moments of all protons of this objects atoms with the direction of the field. Radio frequency electromagnetic field is then used to alter the magnetization alignment of protons relative to the field. Once radio EM frequency is deactivated, protons will return to the original magnetization alignment. Such changes in magnetization alignment of protons create a signal detectable by the scanner. The position of all protons in the body can be determined by using additional magnetic fields during the scan. The sensory data is then used to construct an image of the object. [Branstetter 2009]

2.2.2   Data processing and reconstruction

A number of techniques have been developed for combining field gradients and radio frequency excitations for a purpose of constructing an image [Wikipedia 2011i]. Such techniques include 2D or 3D reconstruction from projections (similar to CT), building the image point-by-point or line-by-line and gradients in the RF field rather than the static field. Although each of these techniques is used for specialist applications, the majority of MRI images are constructed by two dimensional Fourier transform (2DFT) technique with slice selection or three-dimensional Fourier transform (3DFT).
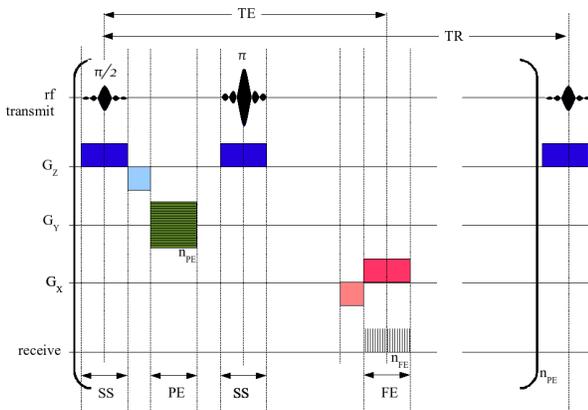
Figure 14: Simplified timing diagram for two-dimensional-Fourier-transform (2DFT) Spin Echo (SE) pulse sequence. Legend: SS slice selection, PE phase shift, FE frequency-encoding, G_i gradient fields, T_r time before the whole sequence repeat itself, TE time of spin echo, n_{FE} number of times the signal is sampled, n_{PE} number of times th whole sequence is repeated. Courtesy of Wikipedia. [Wikipedia 2011a]

First, image contrast is created by the differences in the nuclear magnetic resonance signal from different locations. Usually this depends on relative density of exited nuclei and the differences in relaxation times after the pulse sequence (T_1 , T_2 , and T_2^*) [A. L. Baert 2006]. Carefully designed pulse sequence allows one one contrast mechanism to be emphasized, giving MRI a great advantage with flexibility. For example, in the brain white matter appears white and the congregations of neurons of gray matter appear gray, while cerebrospinal fluid (CSF) appears dark. Just as with the CT, patient may take contrast agents to enhance the contrast.

Very valuable technique in the unification of different MRI techniques is called k-space formalism [Wikipedia 2011i]. It shows that the demodulated MR signal generated by freely precessing nuclear spins in the presence of a linear magnetic field gradient equals the Fourier transform of the effective spin density. The importance of k-space in determining image contrast lays in advanced imaging techniques, like spiral acquisition, where a rotating gradient field is applied which then causes the trajectory of k-space to spiral out from the center to the edges. Due to decay the signal is greatest at the start; acquiring the center of k-space first improves contrast to noise ratio (CNR).

Final imaging step is pulse sequence [Bankman 2000]. Its first part consists of slice selection, which causes a 90 degree nutation of longitudinal nuclear magnetization within a slice, creating a transverse magnetization. The second imparts a phase shift upon the slice-selected nuclear magnetization. In the third par, another slice selection (of the same slice) uses another pulse to cause a 180 degree rotation of transverse nuclear magnetization within the slice. This causes a spin echo to form at a time, during which a frequency-encoding is applied. The signal is sampled a number of-time times. Longitudinal magnetization is then recovered and after certain time the whole sequence is repeated several times, but with phase-encoding gradient incremented. After 2D matrix has been created a two-dimensional Fourier transform is performed.

2.2.3 Field of application

Turning the gradient coils on and off will affect the frequency at which protons resonate. Diseased tissue, such as tumors, can be detected because the protons in different tissues return to their equilibrium state at different rates. This effect is used to create contrast between different types of body tissue. MRI can be used to image every part of the body, but is particularly useful for neurological conditions, disorders of the muscles and joints, evaluating tumors and for showing abnormalities in the heart and blood vessels. [Wikipedia 2011i]

2.3 Ultrasound

Ultrasound imaging, also called ultrasound scanning, sonography or ultrasonography, is a medical imaging technique which applies high-frequency sound waves on the parts of the body in order to visualize subcutaneous body structures like muscles, joints and vessels [Wikipedia 2011t]. The term ultrasound refers to any sound wave withe frequency above 20kHz. It is a very common and widely used clinical procedure during pregnancies. Ultrasound is a noninvasive examination which does not use ionizing radiation. Due to its ability to capture the data in real-time, ultra sound can be used to show the structure and movement of the bodys internal organs, as well as blood flowing through blood vessels. As with the previous modalities, ultrasound procedures sometimes endores the use of microbubble contrast media to enhance the resulting image.

Though ultrasound has a wide range of application, a general-purpose sonograph can be used for almost all ultrasound imaging processes with the help of specialty transducer. Such transducer can be used directly on skin or placed inside the body.

Figure 15: A general-purpose sonographic instrument. Courtesy of Wikipedia. [Wikipedia 2011s]

Figure 16: Linear array transducer. Courtesy of Wikipedia. [Wikipedia 2011f]

2.3.1 Data acquisition

First step in ultrasound imaging is the creation of the sound wave, a process usually done by piezoelectric transducer. Ultrasound machine sends electrical pulses which will make the transducer ring at desired frequencies, usually between 2 and 18 MHz. Focusing of the beam is done using lenses or a set of pulses, or by the shape of the transducer. Ultrasound transducer produces a sound wave which travels through the body and comes into a focus at a desired depth. Materials in transducer help the sound to be more efficiently transmitted in the body [A. L. Baert 2006]. Usually a gel is placed on the patient's skin before the procedure. This will help differentiate between different parts of body, because the wave is partially reflected from the layers between different tissues. In short, sound waves are reflected whenever the density of the body changes.

Sound wave is then returned to the transducer. This is exactly the same process in reverse, where sound vibrates the transducer. Transducer turns these vibrations into electrical pulses, which are sent to ultrasonic scanner. Ultrasound scanner processes these pulses and a digital representation is constructed [A. L. Baert 2006].

2.3.2 Data processing and reconstruction

As desribed in Image Processing in Radiology [A. L. Baert 2006] next step in ultrasonography is determining three values:

- How long does it take for echo to be received from the moment the sound wave was transmitted.

- Focal length is then deduced which enables a sharp image of the echo at a desired depth.

- Strength of the echo, which determines the brightness.

Once these values have been calculated the scanner can determine which pixel will light up and which will not. The scanner also calculates to what intensity and at what hue will each pixel be colored [A. L. Baert 2006]. The result is a digital greyscale image. These images can be displayed through a computer using a frame grabber, which captures individual, digital still frames from analog signal.

2.3.3 Field of application

Sonography is most often used for clinical purposes, because its ability to be used for both diagnosis, as well as some therapeutic procedures [Wikipedia 2011t]. For therapeutic applications it is
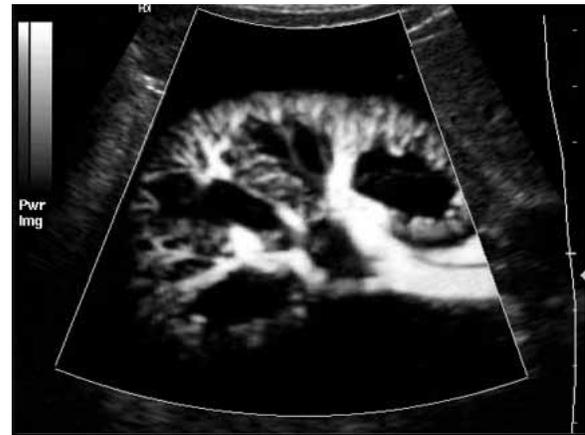

Figure 17: Power Doppler ultrasound of the kidney. This image shows the tiny blood vessels in the kidney like the branches of a tree. Courtesy of Wikipedia. [Wikipedia 2011r]

used to heat or agitate the body, however such procedures use much higher energies then for diagnostic. It is very effective for imaging soft tissues of the body, breaking a kidney stone and generating heat for the treatment of cysts and tumors.

2.4 Positron emission tomography

Positron emission tomography or PET, is a nuclear medicine imaging technique that produces a three-dimensional image of functional processes in the body [Wikipedia 2011l]. It uses a special type of camera and a tracer (usually fluorodeoxyglucose, a sugar), a radioactive chemical which can be metabolized in the body. During the procedure the tracer liquid is introduce intravenously. As it travels through the body much of it is collected in specific organs or tissues. The traces emits positively charged particle positrons, hence the name, which are then recorded by a special camera. PET scan pictures do not show as much detail as computed tomography scans or magnetic resonance imaging because the images show only the location of the tracer. PET scan images are usually matched with those from a CT scan for a more detailed information. It is often used to evaluate cancer, check blood flow or see how organs are working. Three-dimensionality is often accomplished with the help of CT scans performed during the same session and in the same machine.

2.4.1 Data acquisition

First step of every PET scan is intravenous introduction of tracer isotope in the living subject. This tracer is incorporated into a biologically active molecule, which can later be absorbed by the body. Once the active molecules become concentrated in the tissue, a PET scan is conducted on the subject. During the scan the PET machine records as the tracer molecules slowly decay which results in the release of the positron. As it travels through the tissue, it slowly loses kinetic energy until the moment it is able to interact with electrons. The result of the encounter is annihilation of both and creation of photons, which moves in opposite direction of positrons trajectory. As newly created photons travel eventually they reach a scintillator in the PET scanner and result in a burst of light detectable by photomultiplier tunes or silicon photodiodes [Gershon 1990]. This technique requires on simultaneous detection of a pair of photons. Those that do not arrive in pairs are ignored by the scanner.

Figure 18: PET/CT-System with 16-slice CT; the ceiling mounted device is an injection pump for CT contrast agent. Courtesy of Wikipedia. [Wikipedia 2011m]
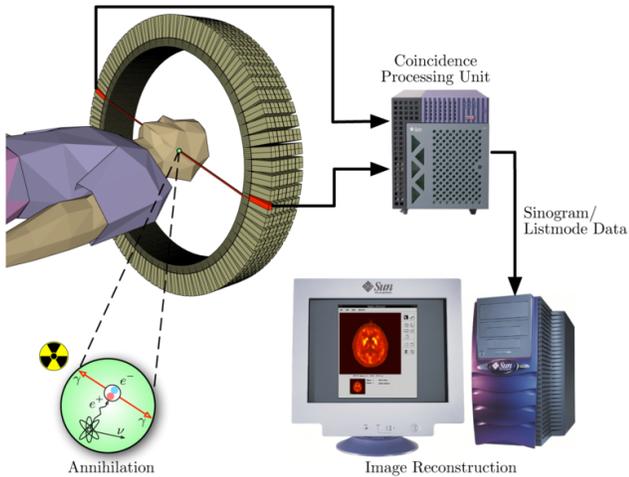

Figure 19: Schema of a PET acquisition process. Courtesy of Wikipedia. [Wikipedia 2011n]

2.4.2 Data processing and reconstruction

The collected raw data of a PET scan is a list of simultaneous detection of photons, an event which resulted in annihilation of electron and its antiparticle positron [Gershon 1990]. Each event represents a line in space connecting the two detectors along which the positron emission occurred. Today, a technique Time-off-flight is employed by scanners to more precisely calculate the difference in time between the detection of a pair of photons.

These coincidence events are grouped into projection images called sinograms. They are analogous to the projections of a CT scanner and can normally be reconstructed in similar way. However, due to the ability of the PET scan data to suffer from random and scatter events, certain preprocessing of the raw data is required [Gershon 1990]. This includes the correction for random events, subtraction of scattered photons, detector cool-down time correction and detector-sensitivity correction. Until recently the filtered back projection (FBP) was used to reconstruct images. It had the advantage of simplicity and low computing requirements. However, due to noise this method had to employ preprocessing corrections. To-
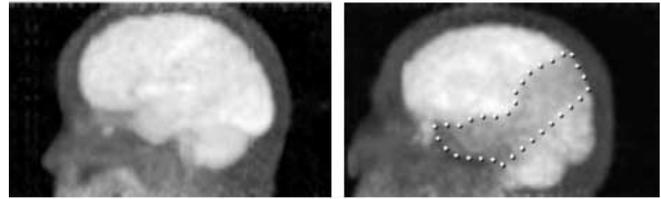

Figure 20: Figure (1) is a PET scan that shows normal activity in a healthy brain. Figure (2) is a PET scan of a brain in a person with Alzheimer's disease. The gray area outlined on Figure (2) shows lower levels of brain activity. Courtesy of Intermountain Medical Imaging. [Imaging 2011]

day, iterative expectation-maximization algorithms are used for the reconstruction, which compute an estimate of the likely distribution of annihilation events that led to the measured data. It has the advantage of better noise profile, but disadvantage of higher computing requirements.

Because of the difference in thicknesses of tissue, resulting photons will attenuate differently [Wikipedia 2011l]. To correct this, contemporary scanners can estimation attenuation CT equipment, integrated in a PET scanner. Attenuation correction has a drawback though, it is susceptible to significant artifacts. For better diagnostic results both corrected and uncorrected images are reconstructed and read together.

While the first PET scanners had only one ring of detectors todays more modern scanner have multiple. Depending on the requirements, each ring can be treated as separate and their images reconstructed separately resulting in a two-dimensional image or allow the coincidence events to be detected between the rings, then reconstruct the raw data as a whole resulting in a three-dimensional image [Gershon 1990].

2.4.3 Field of application

PET has a large area of application, not just in medicine but in scientific research as well. For clinical purposes it is primarily used in oncology to search for for metastases and image tumors, and for diagnosis of certain brain diseases. It is an important technique for treating certain diseases, because of the possibility to target the radioactive chemical introduced in the subjects body. In scientific sense PET scan is used to map human brain and hart function, and in pre-clinical trials which use animals for valuable for cancer research. [Wikipedia 2011l]

2.5 Single photon emission computed tomography

Single photon emission computed tomography (SPECT) is a nuclear medicine technique that uses radiopharmaceuticals, a rotating camera (single or multiple-head) and a computer to produce images representing slices through the body in different planes [Wikipedia 2011p]. SPECT images are functional in nature rather than being purely anatomical such as ultrasound, CT, and MRI. It requires the injection of gamma-emitting radioisotope called radionuclide into the living subject which is attached to a radioligand, a radioactive chemical substance, forming aforementioned radiopharmaceutical. This radiopharmaceutical is capable of being carried and bound to a

Figure 21: SPECT Siemens brand. It consists of two gamma cameras. Courtesy of Wikipedia. [Wikipedia 2011q]

Figure 22: A SPECT scan of a patient with uncontrolled complex partial seizures. The temporal lobe on the left side of the brain shows less blood flow than the right, confirming for the surgeon the non-functioning area of the brain causing seizures. Courtesy of My Field Clinic. [Clinic 2011]

place of interest, which allows the ligand to be detected by gamma-camera.

2.5.1 Data acquisition

SPECT procedure is very similar to PET in its use of traceable radioactive material and detection of gamma rays, but unlike PET scan, gamma radiation of the tracer molecule is measured directly instead of measuring photons [Branstetter 2009]. The resulting image of PET scan has higher resolution then SPECT scan due to more radiation event localization information provided by detectors. The advantage of PET scan is in the ability to use longer-lived more easily-obtained radioisotopes.

Due to the similarity in procedure, SPECT scan also uses radiopharmaceuticals [Wikipedia 2011p]. Gamma camera is then usually rotated a full 360 degrees around the subject and during certain points (every few degrees) projections are acquired. Depending on the number of cameras it is possible for a scan to last up to 20 minutes.

2.5.2 Data processing and reconstruction

The resulting image of this modality has very low resolution, usually 64x64 or 128x128 pixels with the number of projections equal to the width [Wikipedia 2011p]. These images are susceptible to noise and artifacts. Other disadvantage include movement of the subject, which cause significant degradation in reconstruction, and uneven distribution of radiopharmaceutical which can cause in artifacts. Areas of intense activity can cause streaking, a problem which is being solved with iterative reconstruction algorithm which is less sensitive to artifacts and has the ability to correct attenuation and blurring.

2.5.3 Field of application

Most important advantage of SPECT is its ability to create a true three-dimensional representation of the body part, especially in gamma imaging where its used for tumor, infection and bone imaging. SPECT scans have accurate localization in 3D, which can provide more information on localised functions of internal organs like brain and heart. [Wikipedia 2011p]
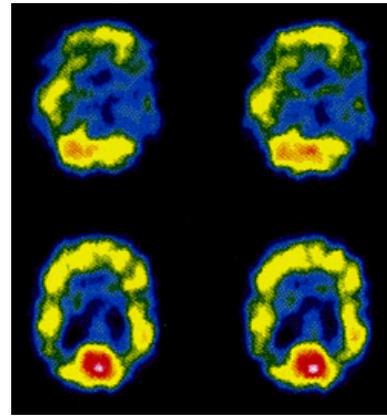
3   Conclusion

It has become more and more apparent that in the world with newer technology and new health risks, more effective and advance imaging techniques are required to diagnose, treat and cure patients. The sheer number of deaths is a good indication of the hundreds of thousands of people who have cancer around the world, and modern medical imaging techniques are capable of diagnosing patients in earlies of the stages, saving thousands. This is but one of many examples that show the need for such technology. Though costs imaging equipment are extremely high their development is of the essence. As it was in times before and as it will be in time after the technical limitations of our times will eventually be surpassed. Newer imaging technology does not only help diagnose the patient in an early stage, but is slowly reducing any risks these machines and procedures may have. Another great requirement of new technology is the computing ability. As stated several times in this paper each technique requires sophisticated algorithms for image construction and correction of any errors it may have, thus showing the importance of parallel development on both fields.

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