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A Review: Tomography Systems in Medical and Industrial Processes

Noor Amizan Abd. Rahman[a,b], Ling En Hong[a], Ruzairi Hj. Abdul Rahim[a*], Herlina Abdul Rahim[a], Nasarudin Ahmad[a], Salinda Bunyamin[a], Khairul Hamimah Abas[a], Nor Muzakkir Nor Ayob[a], Fazlul Rahman Mohd Yunos[a], Muhammad Saiful Badri Mansor[a]

[a]*Protom-i Research Group, Infocomm Research Alliance, Control and Mechatronic Engineering Department, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*
[b]*Institut Latihan Perindustrian Bukit katil, Hang Tuah Jaya, 75450 Melaka, Malaysia*

*Corresponding author: ruzairi@fke.utm.my

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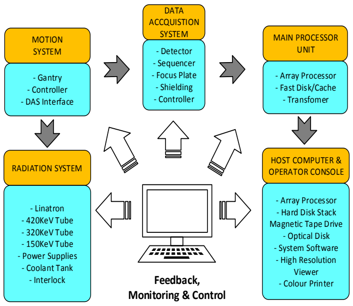
Graphical abstract



Abstract

Conventional methods previously guided reading meter to monitor the process and steps must be taken to interpret the readings and what need to adjustment be implemented. With the use of the method tomography, imaging process that displays the contents of the flow in the pipe or vessel during the process of giving analysts in real time quickly. By so corrective action can be done at a fast rate. The image will be formed from the trajectory of the object or sensor plane passing through the tomographic system. Use tomography method can be adapted to the process or the materials to be monitored. This paper examines the use of tomography in medical and industrial sectors. For use in the medical field such as looking at the structure of tissue in the body, can be used to detect cancerous elements tomography method comprising the X-ray, optical coherence tomography (OCT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), and ultrasound. The industrial sector consists of Optical Coherence Tomography (OCT), Electrical Impedance Tomography (EIT), Electrical Resistance Tomography (ERT), optical Capacitance Tomography (ECT), and Tomography Ultrasonic (UT). This paper discusses the role, the use of concepts, basic design and development impact of the results of research conducted by previous researchers.

Keywords: Tomography concept; operation; application medical and industrial sector

■1.0 INTRODUCTION

Tomography is a method of producing a desired image after carrying out a monitoring process on a solid object, such as in industry or in soft tissues such as the human body, with a view to displaying images of either a 2D or a 3D internal structure by observing and recording the difference in the effect on the circulation of energy waves of the structure to be monitored [1] or a technique for displaying a representation of a cross-section through a human body or other solid object using X-rays or ultrasound [2]. According to the *Oxford English Dictionary*, it is defined as radiography in which an image of a predetermined plane in the body or other object is obtained by rotating the detector and the source of radiation in such a way that points outside the plane give a blurred image. Also, in extended use, it includes any analogous technique using other forms of radiation.

There are also some previous tomography as radiological techniques to obtain a clear picture of the internal structure of a particular part of the human body. This view is seen as a support to the conventional techniques used, namely X-ray. The interpretation of the resulting image through this process reflects the layer structure of the internal organs of the human body escape. However, there are clear differences in the use of X-ray in early stage prior to arrival upgraded techniques such as Computer Tomography (CT), now renamed tomography.

Tomography in culture means a procedure by which waves are sent through an object and a computer produces an image of cross-sections of the object by using information on how the waves are changed. Both ultrasound and CAT scans are medical uses of this technique, but it is also widely used in science and industry [3].

The word "tomography" is derived from the Greek word “tomos”, meaning phenomenon described soiled image of the cross section of the object. The internal structure of an object displayed on the various elements of photons or particles that can penetrate the object and continue to analyse the purpose of obtaining a description of the monitoring signal detector mounted on the monitoring point at which the process is operating systems [4].

Tomography system consists of several basic processes: the detector block that receives data from the sensors, controllers, which maintains data sources, and processing components where the signals received from the raw data is converted to digital signals by the use of appropriate algorithms, processing block using computer support to form a CT scan was developed.

Preliminary findings radiography technology in 1895 when Roentgen accidentally discovered X-ray image of the hand of his wife, Bertha. Imaging produces structural his wife's hand and looked image can be seen on the display ring is formed.

However, there are two types of field tomography: 'hard field' and 'soft field' [6]. Hard field means that regardless of the type of material or medium, the direction of travel of the wave energy from the power source is constant. Examples of hard-field tomography are X-ray Micro Tomography (XMT), Magnetic Resonance Imaging (MRI), and Positron Emission Tomography (PET).

In soft-field tomography, an electric current is introduced into the imaging medium and the electric field distribution is determined by the physical properties of the electrical materials, in order a map of the resistance, capacitance, or impedance can be reconstructed by a computer to form the tomogram [7]. Soft field characteristics are more complex compared to the nature of hard-areas, and much more analysis and computer algorithms are required to reconstruct the image [8], especially with regard to the image-reconstruction algorithm, due to its non-linear form. Examples of soft-field tomography are Electrical Resistance Tomography (ERT), Electrical Capacitance Tomography (ECT), Electrical Impedance Tomography (EIT), and Magnetic Induction Tomography (MIT). Main difference between the two types of tomography for soft-field on emitting tomography did not follow the pattern of straight lines, and distribution of the signal depends on the type of excitation source.

■2.0 DEVELOPMENT OF TOMOGRAPHY APPLICATION IN MEDICAL

The ability to access information on the human body has led to many useful clinical applications. Over the years, different modalities of medical imaging have been developed, each with its advantages and disadvantages.

2.1 X-ray

In 1895, the German physicist Wilhelm Roentgen made the discovery of an electron beam in a gas discharge tube. Roentgen found that the fluorescent screen in his lab began to shine when the electron beam was turned on [9]. Significant events for the world of imaging starts here.

X-ray technology makes it possible to look straight through human tissue to check for broken bones, tooth decay, and swallowed objects with ease. With the development of this concept, X-rays are widely used to examine the soft tissues, such as the lungs, blood vessels, or intestines.

X-rays are essentially electromagnetic energy carried by particles called photons. The difference between X-rays and visible light rays is the energy level of individual photons, which is also described as the wavelength of radiation. The human eye is sensitive to a specific wavelength that is visible, but not to shorter wavelengths of higher energy.

Both photons of visible light and X-ray photons are generated by the motion of electrons in the atom. Electrons occupy different energy levels, or orbitals, around the nucleus of an atom. When the electrons fall into a lower orbital, which is necessary to release some energy, extra energy is released in the form of photons. The photon energy level depends on the extent to which the electrons fall between orbitals [10].

When a photon collides with an atom, the atom can absorb the photon's energy by boosting an electron to a higher level. For this to happen, the photon energy level has to match the energy difference between the two positions of the electron. If not, the photon cannot switch between the orbital electrons. The atoms that make up the body tissues absorb photons of visible light very well. Photon energy levels correspond to various energy differences between the positions of the electron.

An X-ray machine is a pair of electrodes consisting of a cathode and an anode in a glass vacuum tube as shown in Figure 1. The cathode is a heated filament. Heat sputters electrons off the surface of the filament. Positively charged anode consists of a flat disc made of tungsten, which stimulate electrons in the tube. The voltage difference between the cathode and the anode is very high, so energetic electrons fly through the tube. Speeding electrons collide with atoms of tungsten to a lower atomic orbitals. Electrons in higher orbitals immediately fall to a lower energy level, releasing additional energy in the form of photons. Impairment forming a high energy value is then generated from the X-ray photons. Free electrons can also generate photons without hitting an atom. The atomic nucleus can attract electrons quickly enough to change their course. Like a comet whipping around the sun, with the slow movement of electrons with different directions so given way to atomic elements.

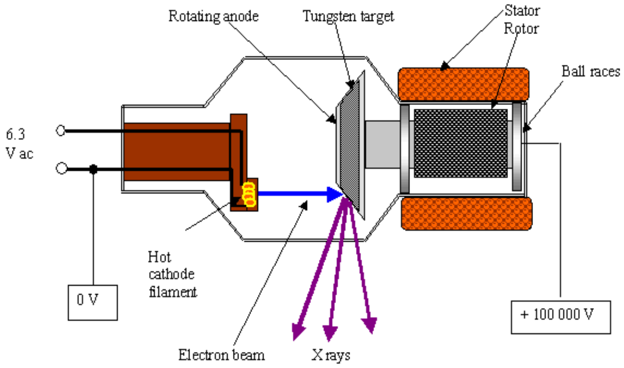


Figure 1 Building an X-ray glass vacuum tube [10]

X-ray applications that are implemented as usual will suffer from rather vague imaging, as most soft tissue cannot be seen clearly. To focus in on organs or to check the blood vessels that make up the circulatory system, there is a method of introducing a contrast medium inserted into the body. A contrast medium is a liquid that absorbs X-rays more effectively than the surrounding tissue. To bring the organs in the digestive and endocrine system into focus, the patient will swallow a mixture of contrast medium, usually barium compounds [11, 12]. To examine blood vessels or other elements in the circulatory system, the contrast medium will be injected into the patient's bloodstream. The contrast medium is often used in conjunction with a fluoroscope. In fluoroscopy, X-rays pass through the body to a fluorescent screen, creating a moving X-ray image. Doctors may use fluoroscopy to detect the path of contrast media through the body. Doctors can also record moving X-ray images on film or video via technology to combine process in digital form named CT scanning.

High-impact collisions involved in the production of X-rays produce a lot of heat. A part of motor to rotates the anode to prevent melting as a result of the electron beam focusing on one area. During the imaging process, almost the entire area is surrounded by a shield to prevent light coming out of a small area in the shielding process. A window allows part of the X-ray photons to escape in a narrow beam. The beam is transmitted through a series of filters to the object/body in the browser. The images are produced in the form of a 2D representation, and the display of the results is called radiography [13]. The dark areas represent less dense structures which allow radiation to pass through, when a white image is displayed showing the structure of compact bone, as shown in Figure 2.

Figure 2 A typical X-ray radiograph of the chest, in which the regions of bone are reflected in white [14]

An X-ray radiation effect due to ionizing radiation interacts with the process. When ordinary light hits an atom, it cannot change the atom in any significant way. But when an X-ray hits an atom, it can knock electrons off it to create ions, which are electrically charged particles. Free electrons then collide with other atoms to create more ions. The ions' electric charge can lead to chemical reactions within the cells. Among other things, charges can break DNA chains [15]. Cell DNA will either die or the DNA will develop a mutation. When cells are exposed to the body can cause various diseases. If DNA mutates, cells can become cancerous, and this cancer can spread. If the mutation is present in the sperm or egg cell, it can cause birth defects. Be of interest to reduce resource limited exposure to the patient or the system operator.

Optical Coherence Tomography (OCT) is a system that uses the concept of barriers in light sensor and transmitter if it exists hindered depending on the sensor signal receiver, however operating at rated micrometer resolution. "Coherence" means it uses broadband light source emitted during the process/object through time and if there is a difference in value of the transmitter received by the receiver then the coherence of the light sensor is produced depending on the original coherence of the emitted light. The basic building structure consists of two arms of the sample arm and the reference arm. The combination between the two arms was compared across the interference pattern of light received by the sensor receiver, there is the use of the scanning mirror in the reference arm, the sample reflectance profiles available to work with time-domain OCT [15]. This scan to get information about the dimensions and structure of the object being monitored. A cross-section can be achieved by combining the depth of the scan in the series axis. Obtained depending on the depth of the imaging process used.

In a conventional interferometer (laser interferometer), light interference occurring over a distance of a meter is reduced to a range of micrometers, and the use of broadband light source can emit light with high speed [16]. A large bandwidth can be produced using a Superluminescent Light Emitting Diode (SLED) or a laser with a short pulse and femtosecond laser. The quality images produced depends on the sensor selected to contribute to the OPV laser source 302, 650 nm, in previous studies, there are four types of photodiode: i) Hamamatsu 597, ii) Hamamatsu 5972, iii) Centronic BPX65, and finally iv) Epigap EPD-660-5. From observation and tests conducted by previous researchers, the sensor selected was the Epigap EPD-660-5 [17]. Type of sensor arrangement method can categories into a two main types: i) parallel beam mode, where the sensor is placed on a one-to-one basis, and ii) fan beam mode, where all sensor activate in wide beams angle, which can provide various projections, but this method provides a critical delay detection period [18].

Optical fibre and parallel modes [19] are a method used to measure the different materials apply to size of pipe diameter 81 mm, quartz halogen to a single source. Use of a Light Emitting Diode (LED) light source and receiver lead photodiode signal, with a set of 16 pairs in the medium term projections are arranged on two sided [20]. The application of a LED sensor element has been used as a source and as a lead photodiode receiver [21].

Issues arise in the degradation of the accuracy of the system and there is also the issue of collimating light, where the problem is relatively low speeds period to get the source data in real-time. Previous research used 32 sets of sensors [22], but the modification used 38 transmitters for a total of 76 units with 35 cm projection as the light source. Testing conducted by the researchers found that the monitoring system for air bubbles of 1–10 mm with a metric number of 11/min and there was also a decision until 15–20 mm metric tracked by the number of 31/min [23]. In addition, the use of an infrared LED with a parallel beam mode used by researchers using emitter LED type TEMIC Semiconductor (TSUS4300) in any wavelength between 900 nm and 1000 nm with a peak wavelength of 950 nm [24]. The infrared signal receiver used a TEFT4300 type phototransistor [25]. It also uses an infrared LED with fan beam mode to support infrared transmitter coupled to optical fibers of SFH 484-2 has a wavelength of 880 nm [26] and a small radius of the radiation angle of 16 inches.

Accidents test phase in which the absorption of light solid material by the object and effect of light diffraction and scattering were ignored. Method apply for fan switch-mode beam, multiplexing is used and the overall receiver signal corresponding to each multiplexing resource with sensor configuration found for fan beam projection method in which the transmitter and receiver are arranged alternately. This study aimed to achieve a high data acquisition rate.

2.2 Positron Emission Tomography

One use of radiological procedures for examining tissues in the medical sector is Positron Emission Tomography (PET). This system is a type of nuclear medicine procedure [27]. This means that a small amount of a radioactive substance, called a radionuclide or by its scientific name, a radiopharmaceutical or radioactive tracer, is used to assist in the examination of a tissue sample. Specifically, PET studies evaluate the metabolism of a particular organ or tissue so that information about the physiological function and anatomy of organs can be assessed in addition to knowing the biochemical properties of the object on the monitor.

PET is also used together with other diagnostic tests such as CT to provide clearer information about malignant (cancerous) tumors and other lesions. However, the cost of the equipment used is very expensive. A new technology system called a gamma camera, where a device is used to scan patients who have been injected with a radionuclide, and are being used with other nuclear medicine procedures are being adapted for use in PET image procedures. A gamma camera system can complete a scan more quickly, and at less cost, than a traditional PET scan.

The PET scanner function uses the device to detect positrons (subatomic particles) emitted by the radionuclide in the organ or tissue being examined. The radionuclide used in PET scans made by a radioactive atom acts to chemicals naturally by the particular organ or tissue during metabolic processes. For example, in a brain PET scan, a radioactive atom used a glucose (blood sugar) to create a radionuclide called Fluoro Deoxy Glucose (FDG), because the brain uses glucose for metabolism. FDG is widely used in PET scans. A radionuclide element is a substance consisting of radioactive oxygen, carbon, nitrogen, or gallium [28]. This radionuclide is administered into a vein intravenously (IV). Next, the PET scanner slowly moves into parts of the body and the results of positrons emitted by the breakdown of the radionuclide are examined. Process begins in gamma rays produced during positron emission, and the scanner then detects the gamma rays. An algorithm run on a computer is then used to analyse the raw source of gamma rays and the information received is used to create an image map of the organ or tissue being studied. The number of radionuclides collected in the tissue affects to imaged tissues are displayed, thereby indicating the status of the organ or tissue function.

2.3 Magnetic Resonance Imaging

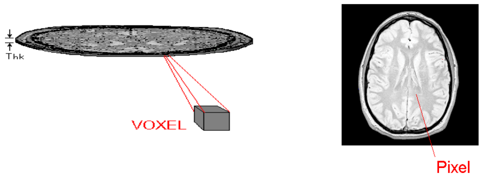
Magnetic Resonance Imaging (MRI) techniques are a method of using the principle of Nuclear Magnetic Resonance (NMR) spectroscopy to support researchers in determining weather information is related to the physical properties of molecules or microscopic chemical data. This technique was introduced by Felix Bloch and Edward Purcell, who were both awarded the Nobel Prize in 1952. In the period between 1950 and 1970, NMR was developed and used for chemical analysis for physical molecules.

While Paul Lauterbur was test a small sample tubes rear projection matching technique in which if examined whether the use of CT. In 1975, Richard Ernst [29] suggested the use of phase and frequency encoding and Fourier Transform in resonance imaging. Imaging with video display with a speed of 30 ms /image [30] was developed by Peter Mansfield with a combination of echo-planar imaging (EPI). Another aachievement by Edelstein in 1986, the imaging process less than five minutes to a level of resolution of up to 10 m/cm of sample. The original concept of echo-planar imaging was originally used by Charles Dumoulin used Magnetic Resonance Angiography (MRA) complement the intended use of imaging blood flow. Exogenous contrast agents can be administered intravenously, orally, or intra-particularly [31].

MRI is an imaging technique tomogram in a sheet by layers image; refer to Figure 3 which has a thickness of each slice images on a scan process. Each image average of 2.0 mm volume elements and each element in the picture is called a pixel, where the light intensity of the Nuclear Magnetic Resonance (NMR) signal is equal to the number of elements of the image.

Thickness of each image slice on a scan

Deletion of some part of imaged anatomical pieces

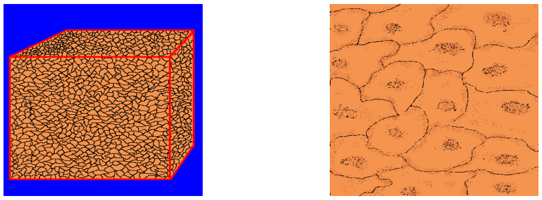


Several volume elements or ‘voxels’

The intensity of a pixel is proportional to the NMR signal

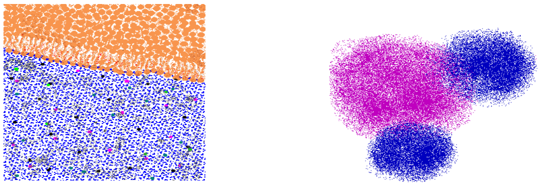
Figure 3 Basic process of tomographic imaging by MRI [31]

The elements in the human body are physically composed of fat and water, which consists of 63% hydrogen atoms [32] (see Figure 4). The nucleus hydrogen consists of NMR signals. While the image voxel human body contains tissue and if the cell is magnified there is a water molecule. The water molecule is made up of oxygen and hydrogen, and thus the hydrogen nucleus is magnified, it can be seen that it consists of a single proton which can be considered as a small magnetic field and can generate NMR signals.



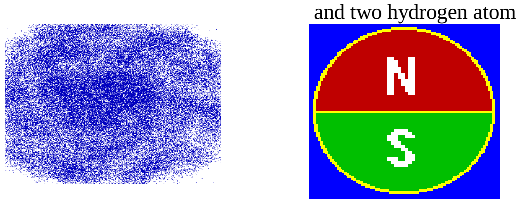
Magnification of a voxel reveals cells

Each cell contains water molecules



Part of the water molecule

A water molecule has one oxygen and two hydrogen atoms



Magnification of the hydrogen atoms

Small magnetic field

Figure 4 Microscopic property responsible for MRI [32]

This upgrades implemented for classification MRI; for example angiography is the imaging of blood flow in the arteries and veins in the body. While the use of CT, angiography is done by introducing X-ray-opaque dye into the human body and creating X-ray images. The use of MRI can produce images of blood vessels in the body. However this technique cannot distinguish between flowing and static blood. Therefore the techniques are inadequate for imaging blood circulation problems. MRA in the exposure of other image results from the bloodstream. The intensity of these images is proportional to the flow velocity. There are three general types of MRA, time-of-flight [33], phase contrast angiography, and contrast enhanced angiography [34].

The method uses a spin-echo sequence in which the selected pieces' 90º and 180º pulses have different frequencies, with a 90º rotation angle stimulating the pulse in one plane, and a 180º angle of rotation stimulating the pulse in the other plane. If there is no flow, no signal can be seen both 90º and 180º pulses. When blood does not flow into the heart at 90º and 180º pulses, no echo is observed. If the location of the pieces in the 180º pulse is now changed to match the location of the blood pulse 90º only blood that will contribute to the signal echo. Phase angiography is a little more complicated. The first new concept is a bipolar magnetic field gradient (GBP) pulse. A bipolar gradient pulse is one in which the gradient is turned in one direction for a period of time and then turned to opposite direction at the same time. A positive bipolar gradient pulse has the positive lobe first and a negative bipolar gradient pulse has the negative lobe first. The area under the first lobe of the gradient pulse must be equal to the second. A bipolar gradient pulse has no net effect on stationary rotation. Spins which have a velocity component in the direction of the gradient will be implemented by the bipolar gradient pulse.

2.4 Ultrasound Imaging

Ultrasound has been used to image human bodies; it is portable, free of radiation risk, and relatively inexpensive when compared with other imaging modalities such as MRI and CT. The images can be acquired in 'real time', thus providing instantaneous visual guidance for many interventional procedures including those for regional an aesthesia and pain management.

The process involves sending a small pulse echo from the transducer into the body. Ultrasound waves penetrate body tissues across different acoustic impedances during the scanning process; these are reflected back to the transducer in the form of an echo signal and some of them continue to penetrate the deeper parts. The echo signal is returned from the plane through the process of successive pulses and is coupled to the imaging process. The basic concept is that an ultrasound transducer functions as a transmitter that is assigned to generate sound waves, and the sound waves are received in the same way as a microphone receives a signal. An ultrasound pulse is actually quite short, but because it crosses a straight path, it is often referred to as an ultrasound beam. The direction of ultrasound propagation along the beam line is called the axial direction, and the direction in the plane perpendicular to the axis of the image is called the lateral direction [35].

The ultrasound transducer is designed using a probe containing various piezoelectric crystals which vibrate in response to an electrical current. This phenomenon, called the piezoelectric effect, was originally described by cutting a piece of quartz to mechanical stress generates an electrical charge on the surface [40]. The crossed to recipient any function that causes the quartz vibration signal [36] to generate electric effects. The sound waves received are measured in units of cycles per second or hertz, while the wavelength is measured in millimeters and the amplitude is measured in decibels.

Organs of the human body that contain air, such as the lungs, heart, and so on, have the lowest acoustic impedance, while solid organs such as bone have a high acoustic impedance (Table 2.1). The echo intensity is proportional to the difference in acoustic impedance between the two media. If two tissues have similar acoustic impedances, then then there is a difference in the results echo scanning. A soft tissue in the human body has the same acoustic impedance and usually produces a low echo intensity [37].

Ultrasound operation is a reflex process of sound energy emitted by the transducer and returned in the form of an echo on the sensor receiver. Reverse echo is called specular reflection, and the intensity of the echo produced is proportional to the gradient of the acoustic impedance between the two media. If the echo signal collision on linear beam angle of 90°, almost all the echoes generated will be returned to the transducer, therefore the beam angle as a factor affecting the amount of the echo signal. Refraction refers to a change in the direction of sound transmission after reaching the interface between two tissues with different speeds of sound transmission. In this case, the frequency of the sound has been set, the change in wavelength accommodate differences in transmission speed of sound in both tissues.

The difference can be seen at the speed of sound is refracted around 1450 m / s for low-fat imaging limits, while the speed of 1.540 m / s in soft tissues [38]. Number of refraction to obtain these results is often used at the intersection of the rectus abdominal muscles and the abdominal wall fat. The result is duplication of structures of the deep abdomen and pelvis seen when scanning through the midline of the abdomen. This is one of the reasons why ultrasound is often used to scan the contents of the uterus.

The results of ultrasound pulses reflector smaller than the wavelength of ultrasound, this issue is identified as a rough surface tissue cells. In this case, the echo is reflected through various angles leading to a reduction in the intensity of the echo. However, the positive results of the deployment of multiple echoes return to the transducer regardless of the angle of the incident pulse. Most biological tissues appear in the image as if they were full of small scattering structures. Speckle signal which provides a texture that can be seen in organs such as the liver or muscle is the result of multiple echoes received is displayed.

Thus the advantages are that the system is portable, secure, and results in real-time feedback. The need to improve the image quality and resolution so that it can be implemented continuously used in many areas of medical diagnostic imaging applications beyond the traditional.

■3.0 DEVELOPMENT OF TOMOGRAPHY IN INDUSTRY

Industrial Process Tomography (IPT) is the equivalent imaging process used in a wide variety of industrial applications. IPT is a relatively new process and is currently still in an early stage of development. It does however offer many important solutions for the monitoring of industrial processes in a non-destructive and non-invasive manner, allowing for the monitoring of chemical processes in order to improve product yield and quality [39].

IPT is not detrimental to the operation process or materials. Use of IPT as a support to the monitoring process is operating and these effects provide a rapid response and dynamic supervision system. For example, on-line control can detect weaknesses that process works. Tomography method in monitoring systems using electrical signals for imaging purposes. A system block diagram is shown in Figure 5. This test method can be used to verify tolerances, to determine relative material densities, to locate inclusions or defects, and to measure the extent of erosion and ablation in composite materials [40].

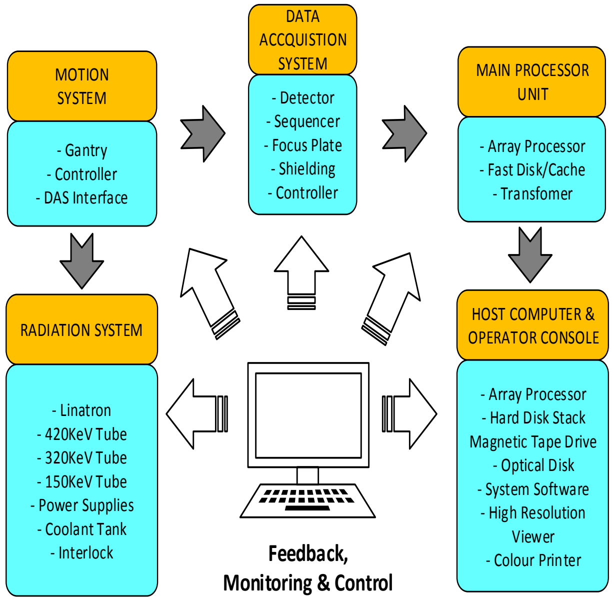


Figure 5 Advanced computed X-ray tomography basic system block diagram [40]

3.1 Electrical Capacitance Tomography

ECT application has previously been used in studies for the analysis of cell survival and is widely used in the industrial sector. Electrical Capacitance Tomography (ECT) is a non-invasive method used to obtain the spatial permittivity distribution within Regions of Interest (ROI), which often refers to the interior of closed pipes. The principle is based on the measurement of the capacitances between electrodes located on the exterior of the region of interest. Reviewing the internal distribution of transparency requires a pictorial representation of the transparency obtained by constructing an image. Images can be constructed by obtaining the prior signals between the capacitor electrodes on the vessel equipped with a capacitive sensor.

ECT can be divided into three groups. The first consists of the capacitance sensor consisting of a variety of electrodes attached to the side of the pipe serves as a capacitive sensor signal changes. The second group includes the unit capacitance for obtaining and processing the signals from the sensor capacitance measurements. At the end of the process, computer control is used to reconstruct and display an image of the transparency distribution using data obtained with various techniques and design options to monitor and control processes that occur in the pipe.

Sensitivity curve was determined using sensors built. This is because changes in plane distance sensor electrode as one source stu to control sensitivity. The wavelength can be controlled by changing the rate sensitivity of the sensor. When it is necessary to amplify the signal, the distance between the sensor and the sample needs to be adjusted. Measures to avoid the occurrence of ground loops or stray capacitance between the control electrode connection need additional function detects noise tolerance. For the control period is the frequency imaging plays an important role [41].

In an effort to increase the effectiveness of the system is the use of ECT sensor for imaging materials, materials used in the frame, pipes and parts, for example polymer composite insulators [42] or saline gel. Limit the size needed depends on the image to be displayed [43]. Whether the position sensor is placed on the interior / relationship with the object or the outer pipe. Decisions rendered image is not affected by extreme temperatures; however, exposure to corrosive effects remain in force during the process is operating. Use of sensor / electrode also confirmed if the outside of the pipe material is made up of materials [44] insulation. High temperature and pressure in this industry is an example of the process flow around a temperature of 300 ºC [45] and pressurized at 150 B [46]. These factors accounted for the pipe diameter is 32 mm.

Minimum axial length of the electrodes is 3.5 cm when using 8-electrode sensor or 7.0 cm if using a 12-electrode sensor. The electrode is made of copper foil and is constructed following Figure 6. Electrode position in radials, can affect the dynamic range for capacitance reduction, in addition to difficulties in data acquisition, although sensitivity increases example diameter between ECT 1–4 inch (2.5cm–10 cm) [47]. Finite Element Model studies of sensors [48–50] were conducted to analysis the effect of radial electrodes on the capacitance and width sensitivity coverage (Table 1).

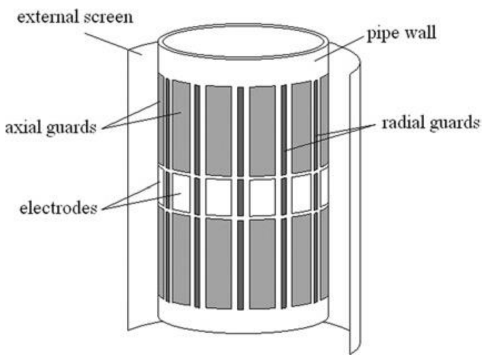


Figure 6 Copper foil and the shielding electrode comprise a shielding cover and radial electrodes [50]

The number of electrodes used also determines the resolution of the whole system. In past research applications, 8–12 electrodes are used for a single plane [51].

Table 1 Relationship with an appropriate number of electrodes monitoring process ECT [51]

No	Number of Independent measurements	Application
6	15	Visualization of combustion flame in an engine cylinder with an attempt to achive 36,000 frames per second
8	28	Imaging of a wet gas separator
12	66	Measuring three-element gas–oil–water flow
16	120	Imaging of nylon polymerization process

The most commonly used ECT sensor diameter size is 4 inches (~10 cm). There is also using 5 cm but the number of electrodes used for the network of 12 independent measurements with values between 0.5 pF, this means that a smaller diameter, the length of the electrode will be reduced [52].

All materials have an electrical capacitance. This is the material's ability to hold an electrical charge. With sensors placed around the container, we can 'see' the different levels belonging to different materials in the container. Information from the sensor as input to a computer for processing, and processed raw data into visual images so that the capacitance can be interpreted directly.

3.2 Electrical Impedance

Electrical Impedance Tomography (EIT) is a non-invasive technique used to scan the material that is monitored by a sensor electrode on the surface of the material and vary the voltage generated is used for image reconstruction process. Imaging is generated by the electrical properties of different materials in the objects, especially the conductivity of the photons inside materials [53–55]. EIT does not use harmful radiation. The most important part of the EIT is the current source power supply (AC). To achieve high resolution image [56], the situation is more stable and continuing the same magnitude and the frequency domain [57, 58] suitable. Use of this system to be subject to the electrode is connected to the scan by measuring the voltage between the electrodes of different arrays. Usually the magnitude of the current is 500 μA, the frequency range is from 100 Hz to 1 MHz [59, 60], and the load resistance is between 200 Ω and 2 kΩ [61]. The security system used by the International Electrotechnical Commission and the American Standards Institute determines a safe time limit for the equipment to be 100 μA (rms)/kHz [62].

EIT method consists of two parts, the first data acquisition hardware is located on the border of the electrode surface. The second part is the signal generator to inject a signal monitoring on objects intersect. Multiplex signal converter with demodulation is used to measure the voltage induced on the surface. Analogue Digital Converter (ADC) serves as a filter is used to avoid the effect of noise on the analogue signal and analogue signal processed by computer for imaging purposes. Signal generator is used [69] to change the output voltage. Operational Amplifier (Op-Amp) is used as a current converter and generate value for the variable low frequency up to 15 kHz. This experiment was performed at 1.3 kHz using 16 silver electrodes placed at equal intervals and detected non-conducting and conducting objects like clay and a copper spindle in a normal saline solution. The current is injected through two adjacent electrodes and the voltages are measured in at every consecutive pair of electrodes. The output data sets are used to reconstruct the density distribution in the closed voltage phantom. However, the resolution of EIT is poor. The performance of an EIT system can be improved by using a larger number of electrodes and increasing the circumference of the phantom. The size of the electrode can be upgraded to the optimum one to achieve the best resolution. More electrodes will offer better spatial resolution, but the previous research found that 16 is the optimal number of electrodes.

3.3 Electrical Resistance Tomography

An ERT system consists of sensors, a data acquisition system (hardware), and a PC with control and data processing software. The sensor consists of a variety of electrodes arranged around the region. Electrodes are used for both excitation and detection. The most common configuration is a pipe or vessel with 16 electrodes, do not disturb the flow in the pipe. In the case of metal pipes, the electrodes need to be insulated. ERT data acquisition systems inject a signal between a pair of electrodes. The most common approach is to apply an alternating current source with a magnitude of tens of milliamps and a frequency of about 10,000 Hz. Sixteen-electrode sensors provide 104 term protocol-independent measurements. Following the acquisition of the voltage sensor sensitivity, the image reconstruction algorithm is used to display the distribution of electrical conductivity in the sensing domain. Commonly used techniques such as Linear Back Projection, Landweber, and conjugate method.

Recent use of the principle of Gauss-Newton gradient and used as a comparison [70]. For two-phase system phase conductivity ratio or difference of pixels that can be counted to determine the diversity or homogeneity of the material through the sensor. Williams and Beck [1] have given a very good description of many topographic measurement modalities including ERT. In comparison with other topographic modalities, ERT is considered to have a high resolution with a speed of 10 milliseconds usually at low spatial, typically 5-10% of the diameter of the vessel to sensor configuration in diameter surrounding the vessel.

ERT imaging of the surface of terrain has been developed for the Department of Environment (DOE) Office of Science and Technology (OST) by Lawrence Livermore National Laboratory (Melia). This innovative technology enables researchers to view 2D or 3D image of the subsurface electrical resistivity at a computer terminal site from several minutes of data acquisition. Such images have been successfully demonstrated for monitoring the recovery process, detecting potential leaks in high-level waste tanks, measuring the movement of moisture in fractured rock, and verifying the effectiveness of a sub-surface barrier. The geophysical imaging technology for measuring electrical resistivity in the soil and rocks to get the image "snapshot". Monitoring is used for sub-surface static for inspection characteristics of the site. It can also be used to obtain information indicates a significant change due to environmental recovery time. The ability to see the difference in resistivity over time eliminates many sources of resistance that remain constant during the recovery and enable selective imaging of changes in recovery. Processes using subsurface heating or steam injection can cause rapid temperature and fluid saturation changes which immediately affect the electrical resistivity.

Electrode arrays consist of bipolar electrodes that communicate with other dipoles. The bipolar electrodes are fastened at regular intervals (usually 5 feet apart) to support the shaft or belt [71]. Electrode arrays can be in very close proximity with one another or hundreds of feet apart, depending on the required resolution. ERT works well for sub-surface of the saturated zone. Result data of measurements taken between the electrode arrays are processed to produce electrical resistivity homographs using state-of-the-art algorithm inversion. Images produced show spatial changes in the electrical resistivity and the location of the electrical resistivity zone on a computer monitor, visual images can be used as a guide to focus on a more detailed characterization, and a monitoring evaluation will be made.

3.4 Optical Tomography

The main concept in optical tomography involves attenuation caused by the refraction of light particles flow to avoid beam projection [72]. The scan process the voltage at the receiver and the imbalance is used to build tomogram it [73]. Based on projections sensor, transmitter and receiver are required to drive the infrared sensor Emitting Diode Lead (IR LED).

To perform optical tomography system operations, it is necessary to adhere to some steps. Either the transmitter or the receiver sensors at around the pipeline in various methods; each sensor will be enabled by changing the cross for each pair; for example, the installation of 16 pairs, a first transmitter is switched on, and then another transmitter is activated after the pair previously activated sensor. At the same time, all recipients will receive a signal for further processing. The same process will be repeated until the last transmitters. After reading the signals received from the transmitter, the signal is sent for processing, where data in analogue form are converted to digital form for the reconstruction of the image. Basically, the system is divided into three main parts consisting of: i) the observer or object detection sensors, ii) the acquisition of data from the sensors, and iii) the processing of the raw imaging data (AC), which are converted to digital form (DC) for analysis [74].

Optical sensors measure the speed of light, which refers to a process in which the data transmission has a high frame rate. This clearly demonstrates the ability of the complete system on a short interval of time. One alternative light source is the use of an LED as a low-switching system design, and high pressure lasers such as SLEDs can also be used. This device can reduce costs whilst capable of operating in real time. Past research also used 32 pairs of transmitters using LEDs and Schottky diodes [75].

3.5 Ultrasonic Tomography

The use of ultrasound systems follows almost the same concept as radar or sonar. Observations are made by evaluating the target by interpreting the echoes from analogue waves. The system has the ability to use active ultrasonic sensor transmitters which produce high-frequency sound waves and to evaluate the echo received by the recipient, but it is also able to measure the time interval for a period of sending and receiving signals representing the return echoes between the object.

Ultrasonic process tomography is the imaging of the response to differences in density and elasticity of the object, for example, to obtain an image of a bubbly gas/liquid volumetric flow in a pipe [76]. In addition, this process helps in finding the details related to the concentration of flow in the pipe. Imaging can be influenced by high noise caused by the collision of particles in the flow pipe and this factor be noted when analyzing the ultrasonic sensor data.

The principle is based on pulse-echo imaging [77], where high-voltage electrical pulses are delivered to the probe, which consists of a piezo-electric transducer that converts the voltage pulse to pulse mechanical vibrations. Mechanical impulse is then delivered to the tissues and organs in the body. This object is scanned before having different acoustic impedance, the echo of that has changed with the electric voltage signal becomes lower. Finally, there is the phenomenon known as' the echo signal, which is received and processed for re-imaging surveillance image-objects.

The advantages of using an ultrasonic sensor in a tomography system are that [78]: i) it is non-invasive, ii) it is safe because no radioactive materials are used, iii) it provides a fast response and imaging scanning process, and iv) only low levels of energy are required to excite the transducer and it does not damage the material investigated.

UT System consists of the hardware and software parts [79] shown in Figure 7. Part of the UT system hardware consists of various sub-divisions such as i) the pulse generator serves to generate a signal and is typically used as a microcontroller to generate pulses with frequency equal to the resonance frequency of the ultrasonic sensor, ii) transmitter, which serves as a pulse of ultrasonic sensor response, iii) ultrasonic sensor as a detector, that it transmitter and receiver.

The prepared sensor ultrasonic transmitter is connected to the amplifier and converts electrical signals into ultrasonic waves on one side of the pipe. On the opposite side of the pipe, the ultrasonic sensor receiver will receives the ultrasonic waves transmitted, which are changed into an electrical signal. The receiver structure consists of low-noise amplifiers, filters, band pass, and some cost data. Return echoes are filtered and converted to a digital signal for processing. As for the software, the process relies on the imaging process using the algorithm chosen by the researchers. A projection algorithm is applied to the digital data gathered to produce cross-sectional images [80–82].

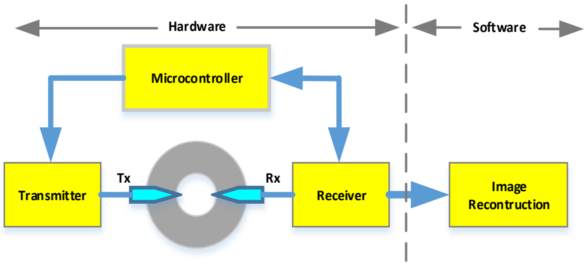


Figure 7 General block diagram of an ultrasonic tomography system [82]

An ultrasonic wave is a category that has a higher frequency than the maximum capacity of normal human hearing. The capacity 20 kHz for adults and the ultrasonic frequency range of the instrument is from 20 kHz up to readings of several gigahertz [83]. The reflection of sound waves from the collision with the surface of a solid object will cause the reflected echo effect.

Distance analysis the function of speed waves emitted by multiplying time spent in the admissions process as below:

Distance = speed x time

Sonar frequencies operate in the range of megahertz. The speed of sound will change according to the material. Factors such as temperature and pressure will affect the speed of sound. In air it is 330 m/s, in water it is 1500 m/s, and in metal it is 5000 m/s [84].

An ultrasonic system has three modes: the transmission modes, reflection modes, and diffraction modes [85]. In addition, it is assumed that the waves propagate in a straight line to facilitate construction of the image with the algorithm. Absorption by the medium and complex sound fields are two major limitations when the transmission mode is applied.

By measuring the change in location and physical characteristics of the ultrasonic waves, the reflection mode can be implemented. In the case of diffraction mode, the measurement is based on the diffraction of the ultrasonic waves at the interface, and most of the research on ultrasonic tomography using this categories of transmission mode.

The transmission mode to apply for imaging of gas/liquid [86], which is a very homogeneous medium. It is based on the transmission sensors and reception sensors of ultrasonic sensors on the surface of circular process vessels. Another design used a system that is intended for imaging of two components (such as gas/water) in a pipe. This system is designed to identify methods of transmission of a multi-phase flow regime consisting of liquid, gas, and solid [88]. This system is a non-invasive type using offline methods. The transmission mode with a fan-shaped beam rear projection was performed using 8 × 8 projection.

The system was developed using 16 transmission transducer element [89]. When to reduce a number of electrode impacts to the sensitivity range of the side modes. Piezocomposite (PZT) is materials for a transducer consisting of a thin rod in the longitudinal direction are configured with a random field embedded in an epoxy matrix.

Tests on aluminum rod of reflection effect is obtained range of results is smaller than the wavelength [90]. The use of low-frequency images of lower-resolution. To restore the resolution, a signal processing method used by deconvolution Papoulis.

Digital data transmission ultrasonic Bayesian filter [91]. It aims to reduce blurring and artefacts, allowing for a more accurate picture. Research using the reflection mode is made using 16 transducers for scan the object to obtain an image of the gas in water [92]. An iterative algorithm based on the model used [93] and ultrasound systems for green wood tomography imaging using non-parametric imaging algorithm. Diffraction tomography can be included as the effect of algorithms to enhance image resolution.

The technique uses diffraction mode is also used to scan tobacco gelatine [94]. The diameter used is 60 mm. The object to be scanned is insonified by a plane wave and ultrasonic pulses are transmitted and measured along a line perpendicular to the direction of propagation of ultrasonic waves. Assumptions weak scattering of ultrasonic waves occur as they traverse the object. Diffraction mode is also used for cross-hole seismic data [95]. A system of ultrasonic diffraction tomography was developed to detect defects in pipelines and large cylindrical structures [96]. Multiples data was detect as small as 50 mm in diameter were detected accurately.

■4.0 COMPARISON OF APPLICATIONS

A summary of different type's tomography by category in the medical and industrial sectors is given in Table 2.

■5.0 CONCLUSION

Monitoring systems using various methods and the overall effects on the imaging process in both the medical and industrial sector have been discussed. This technique is reviewed as the need to define some important equivalent to use. In the field of medical imaging, it is carried out clinically to determine the status of the human body before a decision is made regarding further action. The object of the monitored involves various methods of advantages in terms of image resolution display without damaging other tissues or organs in the human body. Impacts on patient safety are a priority. For use in industry, the transparency factor of the processed data from the image depicted determines the performance of the process. Duration image processing besides the need for real-time operating with an important issue in the election industry. Factor design tools are built and operated, and costs corresponding to the required results also support popular factor of criteria choose in both sectors. The methods presented in this paper provide a guideline for the selection of a suitable system. Hopefully, ideas and innovations previously will upgrade to the level of imaging can improve the ability of existing research and design to meet the selection criteria; for example the level of display quality is better and obviously the ability to use a portable system during the process of design and smaller materials especially the medical sector for health monitoring can be easily implemented without being in a medical center. In addition, the right decision with high speed can increase efficiency to meet the needs of current technology.

Table 2 Differences in the use of tomography between the two sectors

Comparison Item	Medical Tomography	Industrial Tomography
Example of type of use	X-ray, Optical Coherence Tomography, Positron Emission Tomography, Magnetic Resonance Imaging, Ultrasound Tomography	Electrical Capacitance Tomography, Electrical Impedance Tomography, Electrical Resistance Tomography, Optical Tomography, Ultrasonic Tomography
Provision and maintenance costs	Cost of the asset is high and requires a systematic maintenance schedule	Assets are low cost compared with use by the health sector, and complex maintenance is not required
Condition of monitoring object	Static	Moving
Speed of data processing	Low speed for processing	The speed of data processing has to be quick because the measured object moves
Operator requirements	Handling must be done by a competent person	There is no need for a standby person after installation; implementation of the system is easy
Operating environment measurement requirements	Environmental equipment requires a high level of hygiene and the use of care in accordance with the procedures set	Equipment is rugged and robust in order to be suitable for industrial environments with, e.g., oil stains and dust
Effect of radiation	Small risk for patient after improvement. It is necessary to follow the protocol before testing in different tests.	No risk of harm to users operate the equipment or take environmental measurements
Condition involved	Offline:– data capture is fast but data processing is slow	Online: data capture and data reading transfer to imaging in real-time given
Operating mode	The X-ray source and a detector assembly within the system rotate around the patient	Dependent on the requirements of the imaging process; if more sharpness or increased speed is required, more total sensor detection is required

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