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APPLICATIONS OF FINITE ELEMENT METHOD IN COMPUTER TOMOGRAPHY FOR CANCER AND TUMORS: A REVIEW

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ABSTRACT

Computer Tomography (CT) is one of the widely used methods in the field of medical imaging. We can obtain images of any parts of the body including Bones, Muscles, Fat, and Organs from CT. The CT scans of internal organs, bone, soft tissue, and blood vessels provide greater clarity and reveal more details than compared to regular X-rays. One of the best numerical methods to study the behavior of cancerous cells or tumors from CT scan images is the Finite Element (FE) method. The FE mesh consists of three steps. Those are mainly Pre mesh, Mesh, Post mesh. It is efficient to create a 3D Model of these tumors by using Tetrahedral elements. FE method acquires the application such as Data acquisition, Tomographic reconstruction and segmentation, and surface extraction. It is one of the effective tools to understand the mechanical and geometrical characteristics of cancers and predict elastography parameters under different testing conditions. For these applications, high-level meshes are generated using which the analysis of the patient's anatomy is carried out. This technique has the potential to reveal the distribution of Tumor Treating Fields and to acquire the correlation between field strength and survival, which helps to improve the efficiency in the results. This paper thus reviews the study of CT scans using the FE method for cancer and tumors.

KEYWORDS

Finite Element method, Computer Tomography, Cancer & Tumors.

1. INTRODUCTION

Cancer is produced by the unregulated division of cells into surrounding tissues. It is a disease, which is due to changes in DNA. It is one of the most feared diseases. In 2018, around 9.8 million people died of cancer worldwide. It is the worldwide health organization's second greatest cause of death [1-2]. We have 1500 cancer deaths every day in India, according to studies. These figures are truly amazing and frightening. The number of cancers has increased steadily over the last few decades [4].

Early detection and urgent cancer medical therapy are paramount. When the treatment is diagnosed in the beginning, it will become easier and more likely to succeed. The most prevalent forms of cancer death of men and women are prostate and breast cancer. Today, detecting technology has had a favorable impact on the relative survival rate of over 90% in both cancers and so post-treatment quality of life is now a significant element. The traditional treatments of breast and prostate cancer come with many surgical complications and challenges. Ablative therapies have been serving as an effective treatment for cancer, minimizing complications [5].

MRI and MRTI technologies are used to picture the shape and alignment of the tissues along with the temperature field. Image guidance provides real-time treatment monitoring using temperature feedback during the treatment. Whereas ultrasound-guided cryotherapy gives good results [1].

The goal of this work is to provide a review on detecting this dreadful disease of cancer using the most widely used method for solving problems of engineering and mathematical models i.e., finite element method (FEM).

The remaining part of the paper is organized as follows. In section 2, the literature review is provided in brief and a few technologies that use FEM to detect cancer or tumors from CT scans are explained in detail. The finite element method approach for cancer and tumors detection is detailed in section 3 and the study findings are concluded in section 4.

2. LITERATURE REVIEW

FEM is a numerical method for solving a differential or integral equation [6]. In the sphere of medicine, we may identify several of its applications. There are various benefits of FEM in the field of medical devices. The FEM separates a big system into smaller, simpler components that are called finite elements to solve a problem. This is possible through a special spatial discretization within the spatial dimension implemented by the building of an object mesh: the numerical area for a solution with a limited number of points. The formulation of a border value problem in the finite element approach results in an algebraic equations system. The procedure approximates the unknown domain function. [1]

The simple equations which model these finite elements are then combined into a bigger equation system that shapes the whole situation. The speed at which the FEM can run tests on early equipment before expensive prototyping and bench testing is most enticing. The integration of the FEM technique into product development can thereby minimize costs throughout the product development cycle. Investigation of internal organs can be done in two different ways. One is the direct way is by surgical invention and another is by indirect method for example using endoscopes and cameras. A Computer Tomography (CT) scan is a medical imaging technique used in radiology to obtain detailed body scans for diagnostic purposes in non-invasive ways (previously known as computed axial tomography). CT scanning personnel are known as radiographers or radiologists. We can generate anatomical descriptions of various features like CT and Magnetic resonance imaging. CT Scan is the combination of a series of X-Ray images of different angles of body parts. After data is extracted computer processes the cross-sectional (slice) of the bones, blood vessels, and soft tissues inside the body. We use a CT scan or MRI to find the exact cause and the affected portion of the part of the body. A simple view of a CT scan image can be seen in Figure 1(a) and Figure 1(b) shows a schematic image that describes the generation of the model geometry [4]. The extracted data will be stored in the form of Dicom which is very difficult to decode and analyze data for the common man. Here we discuss a few technologies that use FEM to detect cancer or tumors from CT scans.

2.1. Rapid prototyping

Rapid prototyping is a cluster of strategies that are accustomed to quickly fabricating a physical half, model, or assembly victimization 3D package (CAD) knowledge. Here, the creation of the half or assembly is finished by victimization 3D printing. the primary technique for fast prototyping was obtainable within the late Nineteen Eighties. These were accustomed to manufacturing models and image elements. Nowadays, these are used for a spread of applications and are principally accustomed to manufacturing production-quality elements.

Rapid prototyping (RP) includes a spread of producing technologies, though most utilize stratified additive production. However, different technologies used for RP embody high-speed machining, casting, molding, and extruding [4].

Following are the steps in the working process of Rapid prototyping:

1. Create a computer-aided design (CAD) model.
2. STL (Standard Triangulation Language) file creation.
3. Cutting the STL file into slices.
4. Structural support
5. Manufacturing
6. Post-production

A pictorial representation of the steps involved in the working process of Rapid prototyping is shown in Figure 2 and Figure 3. shows the Rapid prototyping model for the medical model.

2.1.1 Need for Rapid prototyping

Rapid prototyping is vital to improve effective communication, reduce development time, reduce costly errors, limit long-term engineering changes, extend product lifetime by adding necessary features, and eliminate superfluous features early in the design.

2.1.2 Application

It is used in the field of making patterns and mold and dies for casting and injection molding and it is used in the electronic and automotive sectors. It is used in the medical industry to develop medical devices and instruments and it is used in the aerospace field of satellites, spacecraft, aircraft, planes, etc.

2.1.3 Advantages

Rapid prototyping helps to scale back the prices of overall development. There's no demand to determine distinguished tools for every new product. Rapid prototyping uses an equivalent CAD and printing instrumentality whenever. The automatic prototyping method conjointly reduces workers' prices. It reduces development time.

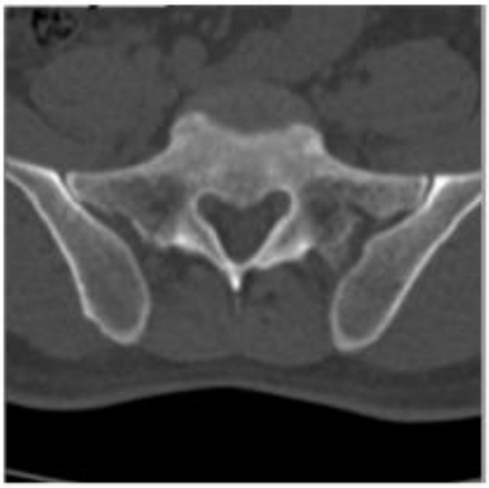

Figure 1(a) view of a single CT scan image [4].

Figure 1(b) Schematic image that describes the generation of the model geometry [4].

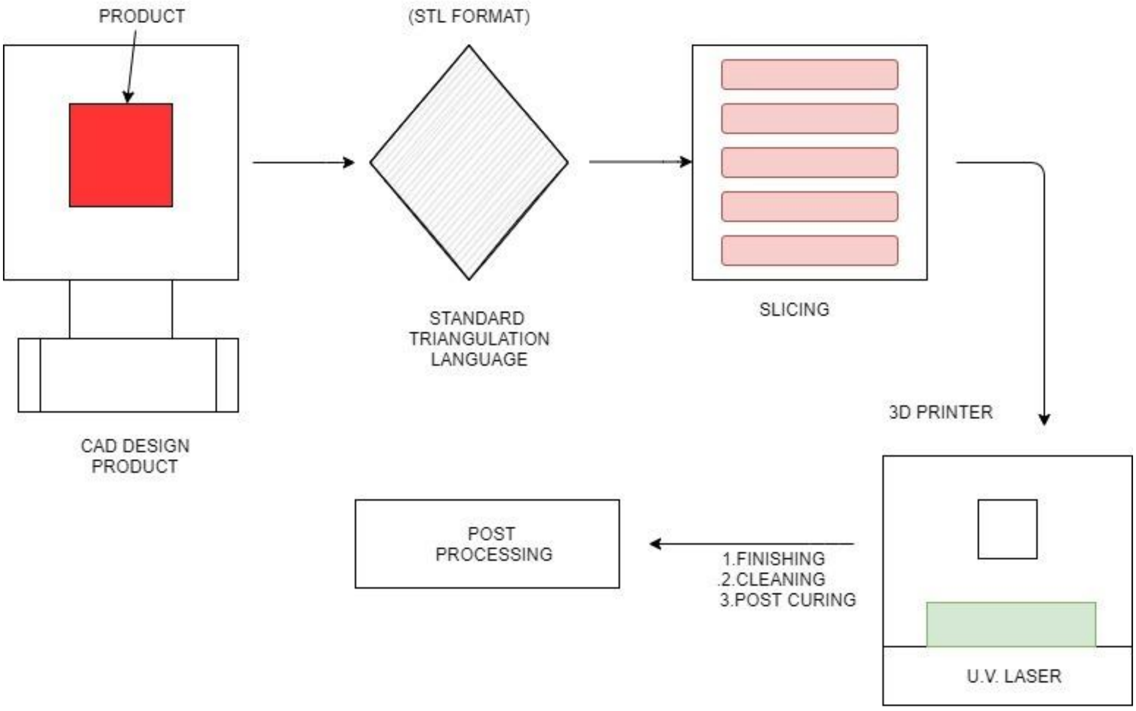

Figure 2. Steps in Rapid prototyping

2.1.4. Disadvantages

One of the disadvantages of this method is that the price of machinery and material is expensive. The strength of the Rapid prototyping part is weaker in z-direction than in others. Also, sometimes staircase effect is observed. Many times, the component gets distorted. Furthermore, limited range of materials.

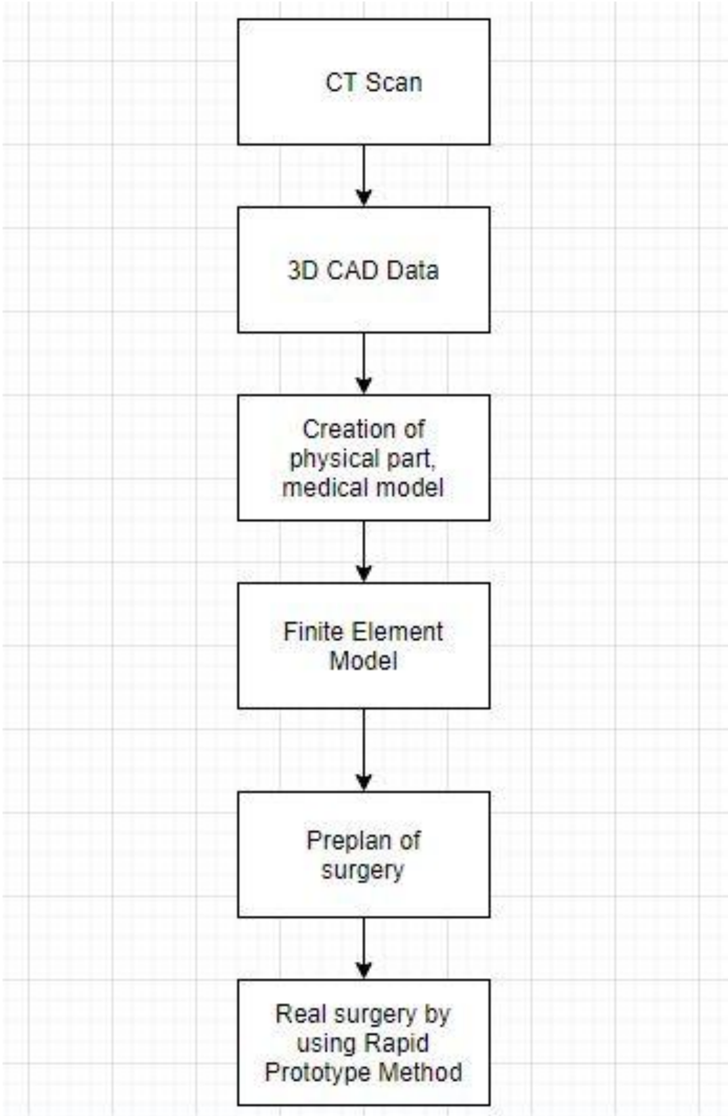

Figure 3. Flow chart showing Rapid prototyping model for medical model.

2.2. Mimic 10 software

Having all the 3D model data (e.g. muscles, veins, etc.) from a CT scan is hard. Since we are not so advanced in getting the CT of the curved part of the body. A CT scan for Cancer Detection is shown in Figure 4.

Computed Tomography is mainly used for bone reconstruction as the bone has a unique CT spectrum 200-2000, thus shading white in a scan. Soft tissue on the other hand cannot be accurately segmented within a CT slice as there is a severe overlapping in grey spectrums of fat, skin, muscles, etc.

The best approach would be to get the bone geometry from Rapid prototyping. Using mimic 10 software is difficult to process (time-wise) and we would probably need a pre-processor for meshing-combining the model entities. This would be very helpful if we both load and perform CFD analysis as it would allow us to set up the model once and export it to two different solvers

(CFD has different mesh requirements than a static or dynamic analysis as it also needs shell mesh).

Figure 4. CT Scan for Cancer Detection [15]

2.3. Osirix imaging software

With the increase in accomplishment Associate in Nursing an emotional collective program, now a day, Osirix has become the extremely wide used DICOM viewer within the universe. Until currently, the analyzers have done the result from the last 17-18 years of research and development within the field of imaging package. It fully supports the DICOM standard for new assimilation in our system environment. Associate in Nursing open platform for the development of process tools is additionally available. Advanced post-processing techniques in 2D and 3D are available. For the best performance on the most prevalent modern CPUs, Osirix supports 64-bit computation and multithreading. Osirix is a raincoat picture process tailored to DICOM images created by CT scan equipment for cancer and tumors. Osirix is a good fit for existing viewers, especially those who are interested in medicine. It complies fully with the DICOM standard for image transfer and file formats. Osirix receives images from any medical imaging modalities transmitted using a DICOM communication protocol [6].

2.4. Volume Rendering Technique (VRT)

Volume rendering is a collection of approaches for displaying a 2D projection of a 3D data set, usually a 3D field. A common 3D information set for cancer and tumors can be a cluster of 2D slice photographs that aren't heritable by a CT scan. Ray begins at the center of the camera's projection (typically the eyepoint) and goes through the image picture element on the imagined image plane floating between the camera and the volume to be produced, using a simple camera model. The ray is clipped by the quantity's bounds, which saves a lot of time. Volume rendering is used in this technique.

Users can view three-dimensional scalar fields via volume rendering. This is frequently required in any industry that generates 3D data sets for analysis, such as physics, medicine, and others. In this case, determining the underlying structure is part of the picture process, and no such assumption is made. Rather, the character of data at each voxel is examined. The optical behavior of the pieces was supported by the analysis, colors and opacities were assigned, calculations were produced, and the structures were displayed [7].

2.5. SPECT

Single-particle emission computerized axial representation (SPECT) is a medical imaging technique that is supported by commonplace medication imaging and tomographic reconstruction methods, and the photographs reflect useful information about patients in the same way that fundamental particle emission imaging does [14].

In contrast to other medical imaging modalities intended for clinical diagnostic purposes, both SPECT and PET provide information that supports the abstraction concentration of injected radiopharmaceuticals [11].

It is worried by a wide range of organs and/or tissue types, depending on the pharmaceutical's biodistribution qualities. Radionuclides that emit γ-ray photons are used to mark most radiopharmaceuticals used in medicine and SPECT. As a result of the imaging device, a scintillation camera system is usually used. The scintillation camera is made up of a lead collimator that allows photons traveling in specific directions to pass through a large-area scintillator (typically a NaI(Tl) crystal) that converts the energy of γ-ray photons into lower-energy photons that are then reborn into electrical signals by photomultiplier tubes (PMTs) [14]. Equipment processes the data from an array of PMTs to provide information about the position at which a particle interacts with the crystal. At intervals around the patient, the scintillation camera projects a two-dimensional image of the three-dimensional radiation distribution or pharmacological uptake [11].

2.5.1. Working of SPECT

The bloodstream is infused with a radioactive tracer. The tracer inside our body emits gamma rays, which are a sort of energy. Signals from the tracer are picked up by a gamma camera, which is then converted into images of blood flow through our heart by a computer. Images of tiny slices cut through the heart can be created from a variety of angles and directions. The tracer's location is determined by examining these photographs. From the thin-slice photos, computer graphics may be utilized to construct a 3-dimensional depiction of our heart.

Areas of our heart with good blood flow will be light on the images, while areas with poor blood flow will be dark. Color images are produced by many SPECT scans. The various colors represent varying degrees of tracer uptake.

SPECT scans can be made during rest and stress tests (called a nuclear stress test). Our doctor will get a better understanding of the way our heart works. If we can't practice, we could take a drug to enhance our cardiac blood flow as though we were practicing. This is known as a pharmacological or chemical stress test.

Blood flow via the coronary arteries is normal if the test is normal during both activity and rest. At rest, the test may reveal normal blood flow (perfusion), but this is not the case after activity. A blockage in one or more heart arteries could be the cause.

Both during exercise and at rest, the test may be abnormal. The tracer will not be observed in this situation. This indicates that at any given time, not enough blood is going to that part of the heart. The absence of a tracer indicates that the cells in that region have died as a result of a previous heart attack.

2.6. PET

Positron emission illustration else remarked as PET imaging may well be a sort of medication imaging. Nuclear medicine uses a small number of radiotracers if any at all. Medication is used by doctors to diagnose, evaluate, and treat a wide range of disorders. Cancer, disturbance, duct, endocrine, or medical disorders, and a variety of other ailments are among them. Medication tests are used to identify molecular activity. This gives them the ability to detect illness in its early stages. They will also show whether or not if we are reacting to the treatment [13].

Except for vascular injections, nuclear treatment is noninvasive and painless. To diagnose and analyze medical disorders, these procedures employ heated materials known as radiopharmaceuticals or radiotracers.

Radiotracers are small molecules that have been "labeled" with a small amount of something. They build up in tumors and inflammatory areas. Otherwise, they will bind to certain proteins in the body. F-18 fluorodeoxyglucose (FDG), a molecule that looks like a simple sugar, is the most often used radiotracer. Cancer cells are metabolically active and can absorb simple sugar at a much faster pace than non-cancerous cells. PET scans reveal this greater rate. This enables our doctor to detect illness before it is shown on several imaging tests. FDG is just one of several radiotracers that are now in use or being developed [13].

The radiotracer is usually given as a degree injection. Otherwise, we did most likely consume it or inhale it as a gas, hoping to pass the test. It gathers in the house at a lower level of inspection. Radiation emissions from the radiotracer are detected by a specific camera. The camera and a laptop computer create video and deliver molecular information [12].

2.6.1. Working of PET

Usual x-ray tests transmit x-rays over the body to form a picture. Radiopharmaceutical or radiotracer compounds are used in nuclear medicine. This chemical is usually injected into our bloodstream by our doctor. Or it might be swallowed or inhaled as a gas. The material accumulates in the examined area where gamma rays are produced. Special cameras detect this energy and use computers to make images that depict the appearance and functioning of our tissues and organs.

PET scans involve only injections from the radiotracer.

In contrast to other imagery approaches, nuclear medicine focuses on body functions. These include metabolism rates or degrees of different other chemical activities. Hot spots are characterized areas of higher intensity. These can reveal high radiotracer concentrations and high chemical or metabolic activity. Less intensive patches, or "cold spots," imply lower radiotracer concentrations and lower activity [13].

3. Finite Element Method Approach for Cancer and Tumors Detection

In modern years, the Finite element method (FEM) is one of the most commonly used methods to imitate the mechanical distortion of tissues and organs during scanning [4].

The outline information of discrete regions of attentiveness must first be extracted from a volume of data before generating a FEM mesh from a medical image. The volume is then meshed into nodes and elements, with material attributes being assigned to each element by the separation information [1].

Commercial FEM software packages such as ANSYS can calculate mechanical stress and strain, as well as anticipate distortion and motion in the field of view, by applying additional boundary conditions and mechanical loadings to the respective nodes or components [2].

The resulted information helps the medical specialists to observe the censorious portion which has the maximum stress intensity and the nodal displacement [6].

It helps in proposing the proper precautions to the patient. The finite element method approach result can help to decide the proper insertion of the proper advantage of the patient [3].

The finite element approach has long been at the heart of numerically solving engineering problems. According to the most recent breakthroughs in the field, higher-order approaches, notably higher-order hp-adaptive systems, hold the field's future. These solutions are ideally suited to the rising number of engineering reflection issues, as well as the general trend of the contemporaneous intention of occurrence with a different plate. Higher-Order Finite Element Methods is a comprehensive overview of the fundamental techniques and practical know-how required to develop higher-order finite element systems.

Higher-order elements are gaining popularity in the finite element area because they capture a more complicated data interpretation than linear elements and lower the number of components necessary to decompose flow behavior, stress, and other modeling types. However, while their representational power simplifies and increases the accuracy of finite element models, visualization and analysis of these new forms of elements are not straightforward.

Although completely automatic hp-adaptive finite element approaches will take some time to become mainstream engineering tools, their benefits are evident. The higher-order finite element technique provides a high-level overview of the inherent methods and empirical knowledge required to implement higher-order finite element schemes [8-10].

4. CONCLUSION

In this paper, we have presented a review of the study of CT scans using the finite element method for cancer and tumors. It is known that rapid prototyping is the best way to transform given data into a 3D model, among all the available methods. We concluded that this method is the best since FEM is commonly stimulated by the mechanical deformation of tissue and other medical images. Therefore, the FEM makes the combination process easy if we want to merge other information with the extracted data. We can get many commercial FEM software packages to compute many variables like stress-strain, deformation, motion, etc. Other than this, it is very easy to use the Rapid Prototyping generation of the 3D model. It does not need too many technical skills and is cost-effective as well. The best method therefore is Rapid Prototyping.

We have noticed that while FE models based on QCT have a great potential for clinical routine use. By using image viewer software, the problem in the conventional method can be reduced. In generating the actual physical model by the Rapid prototyping process, the additional features of the software are quite useful. In the field of cancer and tumor, rapid prototyping has a notable influence. The operating process of such technologies, needs, implementations, benefits, and their drawbacks have been studied. In the medical sector, innovations such as medical imaging, CAD modeling, rapid prototyping, and finite element methods are most important in reducing costs and reducing patient risk.

We have also observed that if the Dicom image viewer software is used the inconvenience of the traditional approach can be resolved. This software allows all 3D contours for simulation to be viewed, thereby reducing the complexity to resolve the medical practitioner's issue. Medical practitioners can easily understand the complex anatomical structure of the patient with the help of this software. In addition, the precision of the numerical solution can be significantly improved by the use of higher-order FEM. Thus, early detection of the diseases can save many lives.

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