Chapter 1 : Tomography - PDF Free Download

Pierre Grangeat (Editor) Introduction to Tomography 1 Pierre GRANGEAT. Introduction 1. Analytical Methods 23 Michel DEFRISE and Pierre GRANGEAT.

Very accurate systems, reproducibility of the basic measurement in the order of 0. Comparison of principal tomographic imaging modalities In most cases, the interaction between radiation and matter is accompanied by energy deposition, which may be associated with diverse phenomena, such as a local increase in thermal agitation, a change of state, ionization of atoms, and breaking of chemical bonds. Improving image quality in terms of contrast- or signalto-noise ratio unavoidably leads to an increase in the applied dose. In medical imaging, a compromise has to be found to assure that image quality is compatible with the demands of the physicians and the dose tolerated by the patient. After stopping irradiation, stored energy may be dissipated by returning to equilibrium, by thermal dissipation, or by biological mechanisms that try to repair or replace the defective elements. Introduction to Tomography 7 1. Localization in space and time Tomographic systems provide images, i. When this grid is two-dimensional 2D and associated with the plane of a cross-section, we speak of 2D imaging, where each sample represents a pixel. When the grid is three-dimensional 3D and associated with a volume, we speak of 3D imaging, where each element of the volume is called a voxel. When the measurement system provides a single image at a given moment in time, the imaging system is static. We may draw an analogy with photography, in which an image is instantaneously captured. When the measurement system acquires an image sequence over a period of time, the imaging system is dynamic. We may draw an analogy with cinematography, in which image sequences of animated scenes are recorded. In each of these cases, the basic information associated with each sample of the image is the local value in space and time of a physical parameter characteristic of the employed radiation. The spatial grid serves as support of the mapping of the physical parameter. The spatial sampling step is defined by the spatial resolution of the imaging system and its ability to separate two elementary objects. The acquisition time, which is equivalent to the time of exposure in photography, determines the temporal resolution. Each tomographic imaging modality possesses its own characteristic spatial and temporal resolution. When exploring an object non-destructively, it is impossible to access the desired, local information directly. Therefore, we have to use penetrating radiation to measure the characteristic state of the matter. The major difficulty is that the emerging radiation will provide a global, integral measure of contributions from all traversed regions. The emerging radiation thus delivers a projection of the desired image, in which the contribution of each point of the explored object is weighted by an integration kernel, whose support geometrically characterizes the traversed regions. To illustrate these projective measurements, let us consider X-ray imaging as an example, where all observed structures superimpose on a planar image. In an X-ray image of the thorax seen from the front, the anterior and posterior parts superimpose, the diaphragm is combined with the vertebrae. On these projection images, only objects with high contrast are observable. In addition, only their profile perpendicular to the direction of observation may be identified. Their 3D form may not be recognized. To obtain a tomographic image, a set of projections is acquired under varying measurement conditions. These variations change the integration kernel, in particular the position of its support, to completely describe a projective transformation that is characteristic of the physical means of exploration employed. In confocal microscopy, for example, a Fredholm integral transform characterizes the impulse response of the microscope. In the last case, describing the Radon 8 Tomography transform implies acquiring projections, i. Once the transformation of the image is described, the image may be reconstructed from the measurements by applying the inverse transformation, which corresponds to solving the signal equation. By these reconstruction operations, global projection measurements are transformed into local values of the examined quantity. This localization has the effect of increasing the contrast. It thus becomes possible to discern organs, or defects, with low contrast. This is typically the case in X-ray imaging, where we basically observe bones in the radiographs, while we can identify soft organs in the tomographs. This increase in contrast allows more sensitivity in the search for anomalies characterized by either hyper- or hypoattenuation, or by hyper- or hypo-uptake of a tracer. Thanks to the localization, it also becomes possible to separate organs from their environment and thus to gain characteristic information on them, such as the form of the contour, the volume, the mass, and the number, and to position them with respect to other structures in the image. This localization of information is of primary interest and justifies the success of tomographic techniques. The inherent cost of tomographic procedures is linked to the necessity of completely describing the space of projection measurements to reconstruct the image. The number of basic measurements is of the same order of magnitude as the number of vertices of the grid on which the image is calculated, typically between and in 2D and between and in 3D. The technique used for data acquisition thus greatly influences the temporal resolution and the cost of the tomographic system. The higher the number of detectors and generators placed around the object, the better the temporal resolution will be, but the price will be higher. A major evolution in the detection of nuclear radiation is the replacement of one-dimensional 1D by 2D, either multiline or surface, detectors. In this way, the measurements may be performed in parallel. In PET, we observe a linear increase in the number of detectors available on high-end systems with the year of the product launch. However, scanning technology must also be taken into account for changing the conditions of the acquisition. The most rapid techniques are those of electronic scanning. In the latter, only a single detector, a radiofrequency antenna, is used and the information is gathered by modifying the ambient magnetic fields in such a way that the whole measurement domain is covered. The obtained information is intrinsically 3D. The temporal resolution achieved with these tomographic systems is very good, permitting dynamic imaging at video rates, i. When electronic scanning Introduction to Tomography 9 is impossible, mechanical scanning is employed instead. This is the case for rotating gantries in X-ray tomography, which rotate the sourceâ€”detector combination around the patient. To improve the temporal resolution, the rotation time must be decreased â€” the most powerful systems currently complete a rotation in about 0. Today, it is possible to acquire the whole thoracic area in less than 10 s, i. The principle of acquiring data by scanning, adopted by tomographic systems, poses problems of motion compensation when objects that evolve over time are observed. This is the case in medical imaging when the patient moves or when organs which are animated by continuous physiological motion like the heart or the lungs are studied. This is also the case in non-destructive testing on assembly or luggage inspection lines, or in process monitoring, where chemical or physical reactions are followed. The problem must be considered as a reconstruction problem in space and time, and appropriate reconstruction techniques for compensating the motion or the temporal variation of the measured quantities must be introduced. Evolution in tomographic techniques manifests itself mainly in localization in space and time. Growing acquisition rates permit increasing the dimensions of the explored regions. Thus, the transition from 2D to 3D imaging has been accomplished. In medical imaging, certain applications like X-ray and MR angiography and oncological imaging by PET require a reconstruction of the whole body. Accelerating the acquisition also makes dynamic imaging possible, for instance to study the kinetics of organs and metabolism or to guide interventions based on images. An interactive tomographic imaging is thus approached. Finally, the general trend towards miniaturization leads to growing interest in microtomography, where an improved spatial resolution of the systems is the primary goal. In this way, we may test microsystems in non-destructive testing NDT , study animal models such as mice in biotechnology, or analyze biopsies in medicine. Nanotomography of molecules such as proteins, molecular assemblies, or atomic layers within integrated microelectronic devices is also investigated using either electron microscopy or synchrotron X-ray sources. Image reconstruction Tomographic systems combine the examination of matter by radiation with the calculation of characteristic parameters, which are either linked to the generation of this radiation or the interaction between this radiation and matter. Generally, each measurement of the emerging radiation provides an analysis of the examined matter, like a sensor. Tomographic systems thus acquire a set of partial measurements by scanning. The image reconstruction combines these measurements to assign a local 10 Tomography value, which is characteristic of the employed radiation, to each vertex of the grid that supports the spatial encoding of the image. For each measurement, the emerging radiation is the sum of the contributions of the quantity to be reconstructed along the traversed path, each elementary contribution being either an elementary source of radiation or an elementary interaction between radiation and matter. It is thus an integral measurement which defines the signal equation. The set of measurements constitutes the direct problem, linking the unknown quantities to the measurements. The image reconstruction amounts to solving this system of equations, i. The direct problem is deduced from the fundamental equations of the underlying physics, such as the Boltzmann equation for the propagation of photons in matter, the Maxwell equation for the propagation of electromagnetic waves [DEH 95], and the elastodynamic equation for the propagation of acoustic waves [DEH 95]. The measurements provide integral equations, often entailing numerically unstable differentiations in the image reconstruction. In this case, the reconstruction corresponds to an inverse problem that is ill-posed in the sense of Hadamard [HAD 32]. The acquisition is classified as complete when it provides all measurements that are necessary to calculate the object, which is in particular the case when the measurements cover the whole support of the transformation modeling the system. The inverse problem is considered weakly ill-posed if the principal causes of errors are instabilities associated with noise or the bias introduced by an approximate direct model. This is the case in X-ray tomography, for instance. If additionally different solutions may satisfy the signal equation, even in the absence of noise, the inverse problem is considered to be strongly ill-posed. This is the case in magnetoencephalography and in X-ray tomography using either a small angular range or a small number of positions of the X-ray source, for example. The acquisition is classified as incomplete when some of the necessary measurements are missing, in particular when technological constraints reduce the number of measurements that can be made. This situation may be linked to a subsampling of measurements or an absence of data caused by missing or truncated acquisitions. In this case, the inverse problem is also strongly ill-posed, and the reconstruction algorithm must choose between several possible solutions. To resolve these ill-posed inverse problems in the sense of Hadamard , the reconstruction must be regularized by imposing constraints on the solution. The principal techniques of regularization reduce the number or the range of the unknown parameters, for instance by using a coarser spatial grid to encode the image, by parametrizing the unknown image, or by imposing models on the dynamics, introduce regularity constraints on the image to be reconstructed, or Introduction to Tomography 11 eliminate from the inverse operator the smallest spectral or singular values of the direct operator. All regularization techniques require that a compromise is made between fidelity to the given data and fidelity to the constraints on the solution. This compromise reflects the uncertainty relations between localization and quantification in images, applied to tomographic systems. As for numerical methods in signal processing, deterministic and statistical methods, and continuous and discrete methods are distinguished. For a review on recent advances in image reconstruction, we refer the reader to [CEN 08]. The methods most widely used are continuous approaches, also called analytical methods. The direct problem is described by an operator over a set of functions. In the case of systems of linear measurements, the unknown image is linked to the measurements by a Fredholm transform of the first kind. In numerous cases, this equation simplifies either to a convolution equation, a Fourier transform, or a Radon transform. In these cases, the inverse problem admits an explicit solution, either in the form of an inversion formula, or in the form of a concatenation of explicit transformations. A direct method of calculating the unknown image is obtained in this way.

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Expected percent improvement in NEC by using singles-based estimation of random coincidences. Figure 5 shows a good agreement between the sinogram space and the image space for the improvement in SNR averaged over all bed positions. We note, however, that these simulations do not model counting rateâ€"dependent effects that may occur in practice. Such effects may degrade image quality at higher counting rates relative to that predicted by NEC rates Similar results were obtained for the other bed positions. The results obtained will vary with changes of lesion size or contrast as well as imaging protocol. The choice of a mm lesion with a 2: Using repeats of measured data to estimate the true image noise from multiple realizations , we then compared 2 methods of reducing the variance of the estimated random coincidences. The results calculated for the mean background value, background noise, and hot and cold sphere SNRs, presented in Table 3 , show that there is no significant difference in image SNRs using either method of variance reduction. For the singles-based estimation method, there are potential sources of error that could lead to different results than those obtained using the smoothed delayed coincidences. For the scanner used in this study, these differences arise from several sources: These factors are affected by the activity levels and distributionâ€"that is, patient size. Phantom studies showed a correction factor variation ranging from 0. The effect of activity level was less significant for the phantom studied, where the correction factor ranged from 0. An advantage for the singles-based estimation method is the reduction by a factor of 2 in the size of datasets that must be transferred and processed relative to the smoothed delayed method. The maximum size of fully 3D sinograms has doubled approximately every 10 mo for the last 2 decades There were no apparent visual differences between reconstructed images using the 3 different methods of estimating for random coincidences. This lack of apparent visual difference has been noted by several investigators, including Badawi et al. In the current study, we measured the true image noise across multiple realizations 50 for simulations, 12 for measurements to determine the average change in NEC and SNR for whole-body imaging. An additional difference with Badawi et al. Excellent timing resolution is thus possible with these scintillators, which allows improved coincidence timing. This leads to a reduced random event rate by reducing the coincidence time window Eq. This improvement, however, is independent of the methods discussed here. In other words, image noise can be further suppressed by using the methods described here for estimation of random events on an LSO- or GSO-based scanner, with the resulting gain in SNR described by Equation A7. The figures of merit analyzed indicated that a singles-based randoms estimation performed only marginally worse than smoothing a separately acquired delayed coincidence sinogram, with the advantage of freeing the bandwidth of the coincidence processor for prompt events only. The improvement obtained in any specific situation, however, will depend on the type of scanner and the imaging protocol. A1 We do not use the voxel root-mean-square RMS standard deviation within the VOI as a measure of noise but mention it here as it is often used, incorrectly, as a measure of image noise. Due to noise correlations present in PET images, the RMS standard deviation is not related directly to the true noise. At best, the voxel RMS standard deviation within a region might be considered a measure of apparent image smoothness. On the basis of these definitions, we define 5 figures of merit for sinogram and image quality: The signal-to-noise ratio SNR in sinogram space is measured for each bed position of each activity concentration as the square root of the NEC rate defined in Equation 1: A4 The root-mean-square error RMSE combines the effects of bias and noise and is a measure of the quantitative accuracy. It is defined for each plane as: A5 The contrast-to-noise ratio CNR is calculated as: A6 where b is the average background value in a plane without targets. The CNR figure of merit is closely related to the nonâ€"prewhitening matched filter, which in turn has been shown to be linearly correlated with human detection performance for simple objects in whole-body PET images such as those considered here The figures of merit were averaged over all VOIs centered in an axial plane, as indicated in Figure 3. From Equations 4 and A2 , we can also derive as a general result the predicted improvement in SNRS k for the sinogram data as a function of k and the ratio of the sum of true and scattered to random coincidences: The authors gratefully acknowledge Drs. For correspondence or reprints contact:

Chapter 3 : NSS/MIC Short Courses

Contents. 1. Introduction to Tomography, Pierre Grangeat. Part 1. Image Reconstruction 2. Analytical Methods, Michel Defrise and Pierre Grangeat. 3.

The job of the Trigger is to quickly discard uninteresting events while efficiently culling the most interesting events in as unbiased a manner as possible. In most experiments the rate at which detector data is sampled, such as beam crossing rate for a colliding beam experiment, is much higher than the rate of physics interactions of primary interest. At the same time the volume of data from digitizing all readout channels is frequently too high to be practically read-out by a data acquisition system DAQ for later analysis let alone be fully reconstructed in real time. Some reduction of needed bandwidth can be achieved within the DAQ system by suppressing channels with no interesting data or other data compression methods. While sparsification can reduce the needed bandwidth by factors of 10 or , suppression by factors of a million are often achieved with a combination of triggering and data compression. This course will discuss the design of trigger systems for particle physics ranging from cosmic ray experiments to future colliding beam experiments such as those at the Large Hadron Collider. The course will cover overall trigger system design with particular attention to impact of beam environment and data acquisition design. It will also cover the design of trigger subsystems which do fast partial event reconstruction and pass information to more global decision hardware. This process is often referred to as generating trigger primitives. The focus will be on primitives that are common to many modern HEP experiments: Also covered will be systems to reconstruct tracks from detached vertices which is a more recent and complicated task. Specific examples from past, current and future experiments will be used to illustrate the techniques of each topic and the progression of those techniques with improving technology. Comparisons will also be made for different types of experiments e. The overall system design of the trigger is very closely coupled to the structure of the beam of the experiment. The particle type, beam energy and timing structure all have a large impact on the rate of particle interactions both interesting signal and uninteresting background. Beam environment can vary from neutrinos produced in the sun no timing structure to proton-anti-proton collisions in bunches separated by 25ns. The complexity of the detector systems also impact the trigger design: The trigger design is also intimately related to the DAQ architecture since the DAQ must feed data to the trigger and the trigger must tell the DAQ what to do with the data. We will discuss how these issues impact the trigger system design. For example, how many decision levels are needed, which levels will be implemented with hardware, which levels with software and which as combination of hardware and software. The design of subsystems to generate trigger primitives must be closely connected to the design of the detector subsystems and the front-end electronics which read them out. These systems do fast reconstruction of event data with a very focussed purpose. To minimize execution time, only certain classes of objects are reconstructed e. Tracks above a minimum momentum threshold. We will focus on reconstruction of physics objects in lower level parts of trigger systems. Since most Level 3 triggers are based on computing farms running off-line type reconstruction code, the design requirements are not particularly unique to the trigger application. The most frequently used trigger primitives are from calorimeters for electron, photon and jet reconstruction along with muons from muon detectors. These have provided and continue to provide standard signatures for many types of particle decays. We will cover these along with the next most common trigger type from reconstruction of charged particle tracks in tracking chambers. These charged tracks are used on their own or matched to objects found in calorimeters e. Recently, very powerful trigger processors have been developed to exploit the long lifetime of heavy quarks b or c quarks from the presence of displaced tracks or detached track vertices. These detached vertex triggers are very challenging but are already revolutionizing triggering in hadron collider experiments. What does the Trigger do? Differences for different types of experiment:

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Chapter 4 : Analytical Properties of Time-of-Flight PET Data - Europe PMC Article - Europe PMC

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Chapter 5 : - NLM Catalog Result

Pierre Grangeat of Atomic Energy and Alternative Energies Commission, Gif-sur-Yvette (CEA). Read publications, and contact Pierre Grangeat on ResearchGate, the professional network for scientists.

Chapter 6 : 13th IEEE EMBS International Summer School on Biomedical Imaging

The principle of tomography is to explore the structure and composition of objects non-destructively along spatial and temporal dimensions, using penetrating radiation, such as X- and gamma-rays, or waves, such as electromagnetic and acoustic waves.

Chapter 7 : Les auteurs de livres vous prÃ©sentent leurs ouvrages - PDF

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Chapter 8 : Tomography - ISTE

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Chapter 9 : Image Reconstruction Algorithms and

Grangeat, P. () Mathematical framework of cone beam 3D reconstruction via the first derivative of the Radon transform, in G.T. Herman and A.K. Louis and F. Natterer (eds.), Mathematical Methods in Tomography, Springer Verlag, Lecture notes in Mathematics No. , pp.