CONF-8910196--1

Noteworthy Application of an Electronic Imaging System

Anatomical Database Generation for Radiation Transport Modeling from Computed Tomography (CT) Scan Data

S. M. Margle, E. P. Tinnel, L. E. Till, K. F. Eckerman, and R. C. Durfee

Oak Ridge National Laboratory*
P. O. Box 2008
Oak Ridge, Tennessee 37831

CONF-8910196--1
DE89 016232

Electronic Imaging '89, Boston, Massachusetts, October 2-5, 1989.

---

*Operated by Martin Marietta Energy Systems, Inc., under contract DE-AC05-840R21400 with the U.S. Department of Energy.

Geometric models of the anatomy are used routinely in calculations of the radiation dose in organs and tissues of the body[1]. Development of such models has been hampered by lack of detailed anatomical information on children, and models themselves have been limited to quadratic conic sections[2]. This summary reviews the development of an image processing workstation used to extract anatomical information from routine diagnostic CT procedure.

A standard IBM PC/AT microcomputer has been augmented with an automatically loading 9-track magnetic tape drive, an 8-bit 1024 x 1024 pixel graphics adapter/monitor/film recording package, a mouse/trackball assembly, dual 20 MB removable cartridge media, a 72 MB disk drive, and a printer. The workstation is shown schematically in Figure 1. Software utilized by the workstation includes a Geographic Information System (modified for manipulation of CT images)[3], CAD software, imaging software, and various modules to ease data transfer among the software packages.

Figure 1.

In the current application[4], CT images are entered into the computer system from magnetic tape media written by the diagnostic CT unit. Polygons defining the boundaries of organs are created and descriptive historical databases produced.

The workstation is operated through a menu-driven interface, allowing an operator to select and activate program modules. The modules communicate through dataset resident tables which describe the state of the user interface, graphics processors, and program entities during operation. A typical session consists of a data previewing phase, a data selection phase, and a data preparation and export phase. The exported datasets are used as input sources for a simulation model which is executed on a remotely located minicomputer and/or supercomputer.

The CT imaging system is an adaptation of a spatial display and analysis tool developed to operate on geographic data such as scanned maps, satellite data, cultural feature polygons, and political boundaries[3]. Typical operations include the selection and preparation of germane data, query extraction of favorable features, and visual validation of combinatorial results. Upon system invocation, a task scheduler presents the operator a list of available modules including the tape access facility, raster image display system, point and polygon data collection and display features, data base manager, graphics processor manipulation tools, data conversion routines, and third party imaging packages. An assortment of system files allows component modules to share the current state of the graphics processor, spatial characteristics of the active image, operator configuration options, and other system-level data dependencies. A database manager with an open and fully defined database structure is used to facilitate information administration. Program units are able to directly read these database files and create database files in this defined format. This allows data files to be viewed, queried, merged, edited, and similarly manipulated by the operator, without additional programming, using an existing database manager.

At initiation of a session on the workstation, a CT tape is inserted into the tape drive. After loading, system software validates the tape format, and presents to the operator a schedule of patients, exams, positions, and images available from the online tape volume. These data are ascertained from information encoded into the tape header by the CT scanning system. The operator may select CT scan data to be previewed on the high resolution graphics monitor, decoded to full spatial and spectral resolution images on magnetic media for later analysis, or both, thereby building up a catalogue of data for an investigation. As a catalogue of images is collected, datasets are automatically created representing CT scanner operation, configuration, registration and calibration, patient and physician reference information, and the CT scan raster pixel data. The operator observes the image collection at full spatial resolution and checks for image continuity, content, anomalies, and accurate organ representation. Visualization aids such as serial image flicker, look up table manipulation, and other image enhancement facilities are used to assist in the selection and judgement. These evaluations complete the input data selection phase.

The data collection phase involves displaying a CT scan on the high resolution monitor and using a mouse or trackball to define the pixel boundaries of the anatomical features of interest. To the polygonal boundary, which is defined to be an ordered and directed set of points, attribute information is assigned by the operator so later processing steps will have available the identity of the tissue types on both the inside and outside of the organ. By local convention, polygons are collected in a counterclockwise manner, inside to outside, from posterior to anterior. The data are converted from raster/pixel coordinate space to a rectilinear coordinate system to allow data validation by the display of polygonal data on any similarly registered image. Conversion routines are utilized to transform these databases to a CAD format for 3D perspective analysis and further validation and plotting as illustrated in Figure 2.

Figure 2.

After data validation is completed, the resulting datasets, which consist of polygonal outlines with organ information, are transformed into the data structures consistent with the requirements of the radiation transport code. This code, which uses Monte Carlo techniques to simulate the radiation transport problem, repeatedly requests information from the anatomical database as to the organ containing a predicted location of interaction of the radiation with the tissues. These questions are answered by "point-in-polygon" routines or through use of a generalized volume-element (voxel) array indexing scheme. Current implementation favors the point-in-polygon approach for partial pixel accuracy; however the execution times of the calculations can be reduced by using the voxel scheme. Future implementations may utilize a hybrid approach for accuracy and efficiency.

Information of the size, shape, and position of an organ is totally contained within the polygon data sets. The volume of an organ is readily approximated from the total area of the polygons enclosing the organ and the thickness of the CT slices. It is thus possible to acquire information on the growth and development of an organ system. Figure 3 illustrates such data assembled on the volume of the lungs of some 44 subjects distributed in ages from birth up to adulthood.

Figure 3.

Physical models (phantoms) representing a 6-month, a 6-year, and a 12-year old were used to measure the radiation dose for a number of common procedures in pediatric diagnostic radiology[5]. The physical phantoms consist of a human skeleton encased in plastics whose radiation transport properties are similar to soft tissue. These phantoms were subjected to CT examinations and the scans were processed as discussed above. Mathematical simulations of the diagnostic procedures were undertaken using the geometric structure derived from the CT scans. Comparisons of measured and simulated dose to radiosensitive organs of the body have been made, and, for example, the computed and measured absorbed dose in the lung per unit exposure for common chest x-ray examinations were found to agree within 5%. The CT-derived anatomical representation of the body provides a degree of realism not possible when ~~the use of~~ quadratic surfaces defin~~ing~~ the boundaries of organs.

These studies have demonstrated that:

1. Routine diagnostic CT scans can provide a means of obtaining anatomical information on children needed for accurate assessment of the radiation dose in tissues of the body.

2. A workstation for processing CT images can be centered around a standard IBM PC/AT microcomputer augmented with appropriate hardware and customized software.

3. Current approaches to radiation transport can be readily adapted to use geometric representations based on polygons or voxel schemes.

4. The geometric representation of the body need no longer be considered as the major source of uncertainty in estimates of radiation dose in organs of the body.

While CT data and the resulting digital phantoms provide a means of eliminating geometry as a concern in radiation transport calculations, it has been our experience that considerable effort is involved in processing the CT images to identify the organs and tissues of interest. Future enhancements will include the networking of the personal computer with a high performance graphics workstation to allow the continued utilization of the existing personal computer peripheral equipment as an economical alternative to workstation level upgrades. The workstation will be used as a compute server to the personal computer. System design will be extended to visualize the results generated by the Monte Carlo radiation transport code.

References.

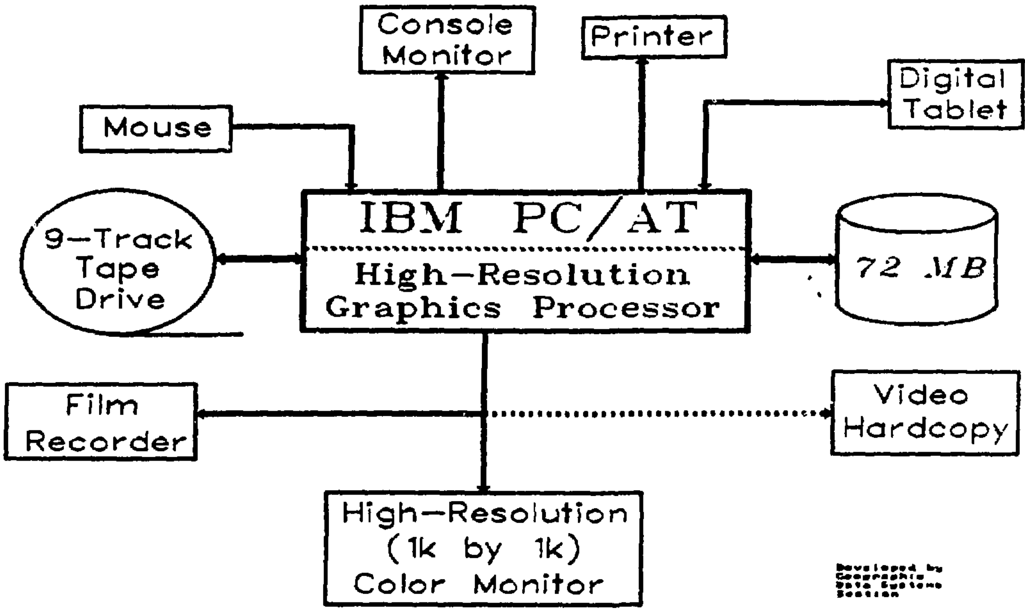
1. R. Loevinger and M. Bernan, "A Scheme for Absorbed Dose Calculations for Biologically Distributed Radionuclides", Journal of Nuclear Medicine Suppl. 1, 1968.

2. M. Cristy, "Mathematical Phantoms Representing Children of Various Ages for Use in Estimates of Internal Dose," NUREG/CR-1159, (ORNL/NUREG/TM-367), Oak Ridge National Laboratory, 1980.

3. S. M. Margle, L. E. Till, B. C. Zygmunt, R. C. Durfee, E. P. Tinnel, "Users' Manual for the Oak Ridge Geographic Information and Analysis System," Project Report for U. S. Air Force IGS Program, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, February 1989.

4. F. G. Dolislager, K. F. Eckerman, S. M. Margle, E. P. Tinnel, L. E. Till, R. C. Ward, R. C. Durfee, "Operating Manual and Principles of Operation for the HASRD Biomedical Workstation," Oak Ridge National Laboratory, TM-11237 (Under Review)

5. T. Fearon, J. Vucich, K. Eckerman, G. Yalcintas, J. Ryman, R.C. Ward, and J. Hoe, "Organ Dose in Pediatric Diagnostic Radiology", Submitted for publication.



HASRD Biomedical Imaging Workstation

Developed by Geographic Data Systems Section

FIG 1

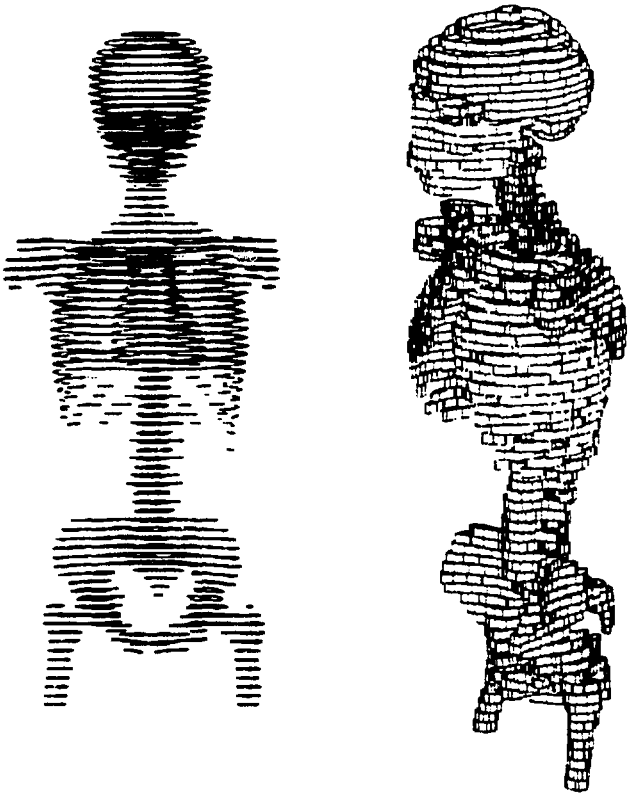
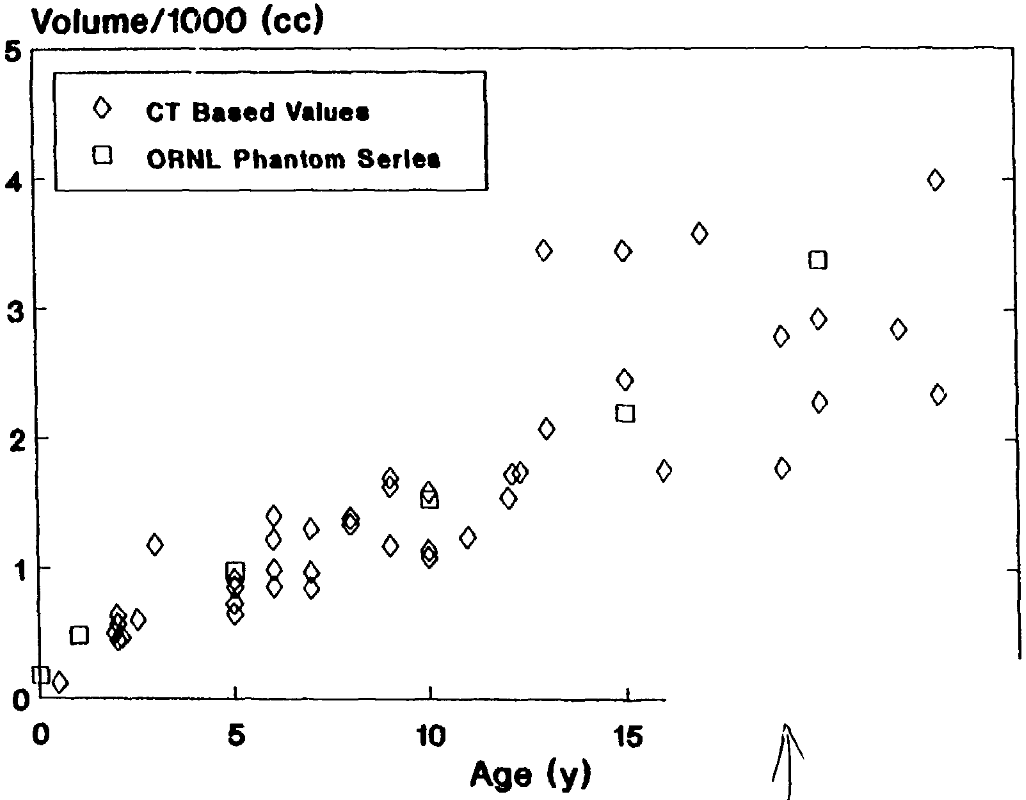


FIG2

Measured Lung Volume



TOP