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Standards Relevant to a NATO Anthropometry Survey Using 3D Imaging Tools

By

James E. Bruckart

Aircrew Protection Division

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United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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Designers of aircraft cockpits and aircrew equipment have long recognized the importance of accurate measurements of the flying population. The success of 3D anthropometry and its usability for design and fitting are dependent largely on the adoption of standards for digital image display, transformation, storage, and communication. Standards are required for image data obtained from surface or volummetric scanner systems, as well as reduced and analyzed data. There are hundreds of data formats already in use by various disciplines for all sorts of data. In this paper, we will discuss what is desired in a format for 3D biomedical image data and several formats already available.

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Foreword

This paper has been prepared for submission to the Advisory Group for Aerospace Research and Development (AGARD) Working Group 20. It is intended as a chapter on image standards for an upcoming report on 3D anthropometry to be published by the working group.

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Background

Designers of aircraft cockpits and aircrew equipment have long recognized the importance of accurate measurements of the flying population. In fact, one of the first symposia of the new Advisory Group for Aeronautical (now Aerospace) Research and Development (AGARD) was devoted to anthropometry and human engineering (1). For example, if an aircraft seat does not provide sufficient height adjustment, a pilot with short stature can not see over the instrument panel. Likewise, a poorly fitted flight helmet comes off the wearer's head and leads to injury in an aircraft accident (2). All components of an aircraft system, including control layout, visual displays, crashworthy or ejection seats, flight clothing, and protective equipment make use of anthropometric data to "fit" the aircraft and life support equipment to the aviator.

The success of 3D anthropometry and its usability for design and fitting largely are dependent on the adoption of standards for digital image display, transformation, storage, and communication. Standards are required for image data obtained from surface or volummetric scanner systems, as well as reduced and analyzed data.

Considering the coordinates of the image elements as independent variables, we have to deal with 2-, 3-, and even higher- (time, frequency, mechanical properties, etc.) dimensional image data. Several types of structures (rigid, nonrigid, static, and dynamic) also are possible. The design of any standards for acquiring, transforming, storing, and communicating biomedical images should include information on the method and body position used for image acquisition.

In a biomedical data processing environment, it is essential also that images from different acquisition systems be capable of integration to produce a composite image with information from each sensor/acquisition system. For example, external anatomical information is needed to interpret data from modern neuroimaging tools, such as X-ray CT, PET, SPECT, or MRI. These external anatomic reference points localize structures in low resolution images, but they can also facilitate the combination of images with different resolutions.

A picture-archiving and communication system (PACS) such as those currently being developed for digital radiology has three major components: image acquisition, image storage, and an image display station (3). A digital network with a computer and image processor system connects these components for transmitting images throughout a hospital, laboratory, or among research centers (4).

Introduction of microprocessor-based workstations provides biomedical researchers access to powerful computers as single user workstations. These computers typically mix computer graphics and image processing capabilities. However, no standard exists that allows users of these workstations to exchange 3D anatomic data in graphic or image form.

The past decade also has produced new opportunities for cooperative research. A broad range of information is available through international data networks. In many geographic areas, the "information superhighway," through computer links, allows workers in common scientific fields to share data and ideas. This ability to share digital information, in standard or formatted data sets, allows the pooling of data into much larger sets. However, before the data can be shared, researchers must understand the format of the data and how to access the information within.

There are hundreds of data formats already in use by various disciplines for all sorts of data. In this chapter, we will discuss what is desired in a format for 3D biomedical image data and several formats already available.

Requirements

When evaluating formats for biomedical images, it is important to consider the following questions.

a. Is the format machine independent? Can you write a file on one type of computer and read it on another type without conversions?

b. Is the format designed for storing numerical data, such as an array of numbers, or for storing graphical data, such as information on line drawings or images?

c. Is the format self describing? In other words, can you read a data file and extract all of its information without knowing anything about the data file beforehand?

d. How general is the format? Is the format specific to a particular type of data or can it store a variety of data types and organizations (matrix, column, or polygonal)?

e. Does the format support annotations inside the data? In other words, can you make notes about the data, add labels, locations, or data values, and store these inside the data file?

f. How widely available is the data format? Is it available as public domain software, as 'free with copyright,' or in a proprietary format? Is the format supported by any commercial vendors or by a standards committee?

g. How widely used and supported is the format? Is there a chance that your colleagues will be able to read your datafiles? Will you be able to read your data files 10 years from now?

h. Can you organize data within a single data file? In other words, can you store multiple data sets in the same file, with some description of each data set? Can you group data sets together inside the data file?

i. Does the format specify what the data file looks like on the disk, or does it instead specify the way the file is written, through a subroutine library? (5)

Digital imaging workstations will be a major component of future 3D anthropometry systems. Many alternative workstations are available, and products evolve such that future systems probably will differ significantly in function and performance from what is available today. To make use of the expensive and changing technology, major characteristics and trends in new technologies must be identified. Data standards should provide current usability, but allow added capability on future workstations.

In a biomedical data processing environment, an essential requirement is the ability to integrate a large class of standard modules for the acquisition, processing, and display of image data. One approach to the management and manipulation of the different data formats is based on the specification of a common standard for the representation of data formats, called "data nature descriptions." This representation specifies not only the structure, but also the contents of data objects (files). Each hardware and software component that produces or uses medical data, is associated with the data objects manipulated by that component. In this approach, a software module converts among the data types required for each component to allow the exchange of data (6).

There are limitations to this approach of using software to transform image data from different postures or different individuals. For example, if a subject is scanned by two different devices, while positioned in two different postures (or positions), it will be difficult for a software module to compare and "normalize" the posture and allow fusion of data from the two images. If body landmarks and posture are clearly defined for an image, they may be used in transforming the image to other postures (where applicable). Fixed references are needed even if there is only a small shift in the position of a single subject in two different images. A similar problem exists when comparing images from two different individuals. Without common landmarks, it is difficult to estimate differences in body segments. Earlier work in this area, by the Tri-service Committee of the Tri-Service Aeromedical Research Panel used linear anthropometry and mass distribution data to construct 3-dimensional human analogues for male aviators. The researchers concluded that the anthropometric data, generated from multiple regressions on stature and weight, were suitable for models to test responses to impact and mechanical forces, but were not recommended for other purposes such as sizing clothing and personal protective equipment or workspace design (7). The problem of pooling 3-dimension data is vastly more complex and will require the identification of landmarks and body positions for each image before images from different persons can be compared.

Another major obstacle to sharing and pooling image data is digital networking. Digital network development has emphasized text information communication which is primarily done one line at a time. A conventional 2D x-ray image has the equivalent of 50,000 lines of information. To transmit such an image using current communications protocols, would take a long time (4 to 10 seconds) (8). Transmission of 3- or higher dimension data, using current data structures, will increase this time exponentially.

The design of the user interface is also an important characteristic of imaging and retrieval systems. In biomedical research and other work situations where computerized information systems are used, the purpose of the work performed by the professional is not operating the computer. The computer is only a tool that supports the purpose of the work. This means the interface must be designed outgoing from the goal to optimize the work activities. The practical consequence is that the design must be based on how information is used in the actual work context and automating these tasks. A good understanding of the user is a necessity and should include such areas as their skill level, education, frequency using the application, other tasks and applications being used, and organization of the work environment (9).

Data formats currently in use

This section describes important data formats and standards currently in use in medicine, computer graphics, electronic communications, and computer-assisted manufacturing. While no single standard currently in use is likely to fully meet the needs of biomedical imaging, it is desirable to share features or maintain commonality with available standards when applicable.

During the past decade, the concept of Picture Archiving and Communication Systems (PACS) has evolved and matured to integrate digital image information in a hospital. PACS integrate various imaging devices, database archive systems, and image viewing workstations. One of the most difficult problems for integration is the standardization of communication protocols required to connect devices from different vendors.

The publication of the American Association of Physicists in Medicine (AAPM) Report No. 10 was the first attempt to standardize image formats in the medical imaging community. Since then, three other groups have formed (CART, the Scandinavian collaboration for Computer Assisted Radiation Therapy treatment planning; ACR-NEMA, a collaboration whose purpose is to formulate a standard digital interface to medical imaging equipment; and COST B2 Nuclear Medicine Project, a European collaboration whose purpose is to define a format for digital image exchange in nuclear medicine). The AAPM format uses key-value pairs in plain text to keep track of all information associated with a particular image. The radiation oncology community in the U.S. has been defining key-value pairs for use with CT, nuclear medicine and magnetic resonance (MR) images. The Cost B2 Nuclear Medicine Project also has adopted this format and together with the Australian/New

Zealand Society of Nuclear Medicine Technical Standards Subcommittee, defined an initial set of key-value pairs for Nuclear Medicine images (10).

In 1983, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) formed a committee to develop standards for the interconnection of digital imaging devices. Version 1.0 of the standard, published in 1985, specifies a hardware interface supporting point-to-point (not network) image transmission, a data dictionary (rules for encoding information), and a set of commands to initiate transactions. Version 2.0, published in 1988, addresses point-to-point transmission and provides rules for data to transit from one device to another (11). Version 3.0, also referred to as Digital Imaging and Communications in Medicine (DICOM), was finalized in 1992. The DICOM standard adds network support by conforming with the International Standards Organization reference model for network communications, addresses the issue of how a device react to commands and data being exchanged, and incorporates the concept of object-oriented design by allowing the addition of information objects, not only images or graphics (12). DICOM image data is stored as a 2D matrix of unsigned or signed integers. The header for a DICOM file is a variable length record that describes the data.

Multidimensional image data is becoming more common in biomedical imaging and has spawned a generalization of the ACR-NEMA standard for two-dimensional images. This exchange protocol is implemented and actively being used in data-, application-, and machine-independent software environment for the visualization and analysis of multidimensional images (13).

Computer Graphics Metafile (CGM) is used for computer graphics including bit-mapped images and vector objects. A CGM metafile can be used to store and organize several images. CGM files are considered fairly machine-independent and allow the incorporation of nongraphical and nonstandardized information into the datafiles.

Data Exchange Format (DXF) is used widely in computer-aided design applications to store polygonal data. Each data element consists of two lines including the "type" code (indicating if the element is an x- or y-coordinate, etc.) and the actual data. DXF was created for AutoCAD, but has since been adapted by other application software companies.

Postscript is a proprietary graphics format developed by Adobe Systems, Inc. primarily for use in printers. It is a computer language that describes pages consisting of text, graphics, and raster images. Postscript is primarily and ASCII standard and not designed for storing numerical data.

Initial Graphics Exchange Specification (IGES) is a general format for transporting and storing polygonal data for CAD systems. It supports a more general set of geometry types than DXF and is designed to be system-independent.

PICT is the primary graphics standard for Macintosh computers. PICT can store image data as 1 bit up to 32-bit unsigned integers. Besides the images, PICT files also contain information on lines and characters.

Tagged Image File Format (TIFF) was developed by Microsoft and Aldus for machine-independent storage of images. TIFF data is stored one image at a time in a tagged data block. TIFF then defines a linked list of tag blocks. TIFF is one of the most commonly used standardized data formats, especially for the storage of 2D image data.

Hierarchical Data Format (HDF) is an extensible, binary, public domain file format specification for storing data and images. HDF files can store floating point data, scaling information, color images, text annotation, and other items. It originated at the National Center for Supercomputing Applications (NCSA) at the University of Illinois to solve the problem of sharing data among different computers. NCSA maintains and distributes a public domain software library to read and write the HDF format. It runs on a variety of computers including Macintosh, Sun, VAX, Silicon Graphics, and Cray UNICOS. The base code is written in C with both FORTRAN and C supported for making calls to the HDF libraries (5).

Summary

Standards for image identification, file formats, and data communications are needed to prevent a proliferation of proprietary standards among manufacturers of biomedical imaging devices. These standards should be flexible, widely available, easily implemented, and allow easy transformations. A significant barrier is definition of landmarks that will allow fusion of different images on one subject or comparison of images from groups of subjects.

A large number of data format and communication standards exist for computing, medicine, and graphics. No single standard is readily available that fully meets the requirements for 3D biomedical images. The final standard adopted for this application is likely to be an extension of an established standard.

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