An Update on American College of Radiology-National Electrical Manufacturers Association Standards Activity

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The American College of Radiology-National Electrical Manufacturer's Association (ACR-NEMA) Standard was published 5 years ago. Implementations are just now becoming available in a form other than a prototype. Though this seems like a long interval between the initial work and results, the organization responsible for the standard, the ACR-NEMA Digital Imaging and Communications Standards Committee, has not been idle. Much of the progress which has been made is the result of cooperative work involving industry, the Committee and its Working Groups (WG), and the medical imaging user community. This paper will briefly review the history of the development of what is now a family of ACR-NEMA standards, describe the current activity of the WGs, and indicate in what directions the WGs are headed for both new and updated standards.
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AT THE FIRST picture archiving communication system (PACS) meeting, held in 1982, the problem of acquiring image and image descriptive data from different manufacturers' equipment was already apparent. Most groups doing PACS related work were using digitized video (which has the disadvantage of limited dynamic range) or magnetic tape (which is comparatively slow). The latter method also often meant "breaking" the manufacturer's "code," ie, understanding the tape format and pixel packing method. The desire to acquire digital data in a direct manner was strong, but vendors were cautious about revealing how their software worked. The potential users of PACS, the radiology community, asked the American College of Radiology (ACR) whether a solution could be found. The engineering contingent within

the manufacturer camp also began to realize that there was little to be gained by keeping image formats proprietary. The result was the formation of the ACR-NEMA Digital Imaging and Communications Standards Committee in early 1983.

The original objective of the Committee was to develop an interface so that image and related information could be exchanged between a piece of medical imaging equipment and whatever was on the other side of the interface.¹ In defining this as the objective, the Committee restricted its range of activity. The resulting standard would not be a full PACS standard, nor a database standard, nor a network standard. However, the ability to bring digital image information out of a piece of equipment over standard hardware using a standard format was felt to be a goal worthy of such concentrated research.

The Committee empowered three Working Groups (WG) to accomplish the task defined. The Working Groups were assigned to hardware and protocols (WG I), data format (WG II), and system performance specifications (WG III). The full Committee assured coordination of the groups and the participation of members in more than one group ensured that communication between groups would be simple.

The WGs began their tasks by examining existing standards. This effort continued until quite late in development (the manufacturing automation protocol/transaction-oriented protocol Standard was considered even after the draft ACR-NEMA document had been written) since it was the intent to use other standards if possible. Other standards examined (for hardware) included Institute of Electrical and Electronic Engineers (IEEE) 488, Ethernet, Intelligent Peripheral Interface, small computer systems interface, DEC DR11W and DEC Unibus (Digital Equipment Corporation, Boston, MA), and Multibus. Standards for data formats included American Association of Physicists in Medicine (AAPM) Magnetic Tape, LANDSAT, NATO magnetic tape, and the Japan Association of Medical Imaging Technology (JAMIT). While

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some ideas were drawn from these, none in particular was satisfactory for all the requirements defined. In addition, because of antitrust regulations in the United States, NEMA must operate under certain constraints. This prohibited the use of certain proprietary interfaces, or interfaces that would unfairly benefit a single manufacturer.

The result of this work was that a new standard had to be defined and the WGs set out to accomplish this as rapidly as possible. The WGs went through numbers of proposals by circulating them to each other and the engineering staffs at the parent companies. Within 2 years, a standard had evolved that was felt to meet all the requirements set forth by the Committee. Following Committee approval, the document was approved by vote of the member companies and ACR representatives. It was distributed at the Radiological Society of North America meeting in 1985 and published as a NEMA Standard (ACR-NEMA 300-1985) in the same year.²

WORKING GROUPS AND THEIR ACTIVITIES

Following publication of ACR-NEMA 300-1985, it was recognized that more work was necessary as additional requirements were made known to the Committee. New WGs were formed to examine these new issues. Initially, WG IV was assigned data compression, WG V exchange media, and WG VI began to address validation. Two other WGs were added subsequently: WG VII for multidimensional data, and WG VIII to develop a standard for hospital information systems (HIS)/radiology information systems (RIS)/PACS communication.

Working Group IV: Data Compression

The vast volumes of data generated by medical imaging departments put a strain on archival media, even optical disk. The communications systems, which must handle the volume, are also burdened. To help alleviate this problem, investigators have been examining data compression. This paper will not address the benefits of lossless versus lossy data compression because this was not the task of WG IV. Rather, the WG sought to allow for data compression and decompression in a manner consistent with the existing Standard.

It was recognized that data compression usu-

ally consists of two steps. In the first, the data is operated on so that it can be represented in a different way. For example, differences between pixels might be computed so that the data may be represented by these differences rather than the full pixel values. The second step consists of coding the converted data so that less space is needed for its storage. In reviewing compression methods applied to monochrome medical images, three popular conversion methods and three coding techniques were identified.

Supported conversion techniques are (1) differential pulse code modulation (DPCM), (2) discrete cosine transform, and (3) the pyramid (and its relative, the S) transform. DPCM is a method that represents original data by a set of differences. The discrete cosine transform is a real valued transform for which fast algorithms exist. The pyramid and S transform are also differencing methods, but compute sets of differences (in horizontal, vertical, and diagonal directions) from pixel data. The pyramid and S transforms have an advantage over others in that viewable images, reduced in resolution, appear at each step.

Once converted, the coding methods take advantage of redundancy in the data to do the compression. The compression standard supports run length, Huffman, and Lempel-Ziv methods. Depending on how the data are quantized, the compression may be bit-preserving (lossless) or non-bit-preserving (lossy). An example is in quantizing the cosine transformed data. If the quantization extends out until transform values vanish, there will be no high-frequency information lost. Truncating the transform data before this point will cut off such high-frequency information.

Another popular compression method, which is lossless but does not fit well into the above list of methods, is perimeter encoding. In this technique, which is used for nonrectangular images, the zero values outside the actual image area are not saved. A map describing the number of pixels per line is sent instead. This method is also supported by this standard.

The design of this standard is such that methods may be combined if such combination will yield more compression. The compression standard consists of new groups and elements that allow a device to describe how compression was

may create problems for the programmer writing the tape handler if the source machine uses the opposite byte order to store data. Those who preferred the fixed byte order argued that the problem was not a difficult one to solve, and that allowing a choice of byte order could result in a nonstandard. At the time of this writing, the proposed standard is being reballoted. A letter explaining the controversy has been drafted and will be circulated with the proposed standard.

The most recent work of WG V has been the reviewing of a Japanese proposal for a standard for erasable optical (magneto-optical) disk. The work is very nearly complete, and adheres to international standards for physical media and format. This standard would cover the 5.25 inch medium and shows great promise.

Working Group VI: Validation

WG VI was formed to examine issues related to validation of the "parent" standard. This includes both validation of the Standard itself, and assisting those implementing or testing hardware and software for the Standard. The WG is the clearinghouse for questions about the Standard and for suggestions regarding new groups or elements. This group is also examining issues related to revision of the Standard, and defines how revisions will be compatible with prior versions. The basic guideline has been that no element would be changed or replaced unless found to contain errors. Errata sheets for the Standard and a definition of the minimum requirements were two efforts of the WG.

The first revision of the Standard (version 2.0) has been letter balloted, approved, and published (ACR-NEMA 300-1988). This revision includes new elements for definition of an identification hierarchy, elements added for ultrasound, and commands and elements added to support laser film writers and other hardcopy devices. All changes were compatible with version 1.0 of the Standard.

WG VI has been the busiest, and its work continues. As discussed in a later section, the revision for version 3.0 is presently being studied.

Working Group VII: Multidimensional Data

With the increasing interest in images which are of multiple spatial dimensions, or which include parametric or time-sequenced data, WG VII was formed to examine how such data could

be accommodated in ACR-NEMA 300-1985. The Standard specifies that images are rectangular with the number of dimensions allowed to be "2."

This WG has some working proposals for member use, but has suffered from difficulty assembling all members for meetings. Some of the newer work of WG VI may supersede the activity of this group. The WG is nonetheless seeking suggestions from interested users or manufacturers, and would be brought back to full active status if sufficient interest is evident.

Working Group VIII: Hospital Information Systems/Radiology Information Systems/PACS Interfaces

The newest of the WGs is defining a standard for interface of HIS, RIS, and PACS. Unlike the parent Standard, the product of WG VIII will be a standard that addresses the upper layers of the ACR-NEMA structure (or, international standards organization-open systems interconnect (ISO-OSI) reference model). It will build around the parent Standard so that ACR-NEMA messages (or parts) may cross from HIS to RIS to PACS and back.

The necessity of this effort is based on the requirement of having certain RIS- or HIS-based data in the PACS (patient demographic information, for example), and getting PACS data (such as time of examination) back to the RIS or HIS. Allowing direct exchange reduces the problem of operator errors in transferring information between systems. Currently, much patient information has to be re-entered in the PACS. Errors lead to database inconsistency that can result in an inability to access data or duplication of files. A similar situation pertains to PACS data which must be copied into the HIS or RIS.

A problem facing WG VIII is that there are numerous vendors of HIS and RIS, and producing a standard that encompasses the data structures of all of them is daunting. Data standards are not being ignored by the HIS/RIS community, however, Health Level and the Health Information Systems Coordinating Council, Health Level 7 committee, and the IEEE Medix committee have been addressing the idea of standards for such systems. Working Group VIII

maintains a liaison with these groups so that compatibility among the standards efforts will more easily be achieved. Joint meetings with the principals of these standards groups have been held and have included European and Japanese counterparts. There is strong agreement that cooperation will benefit all who are working on such standards, and mechanisms to ensure compatibility are presently being worked out.

Joint work with WG VI has been particularly important in considering the requirements of WG VIII. The concept of a "folder" structure is one example of a joint development. Use of the folder mechanism allows communication of patient information (images, text, and other data defined between two communicating systems) as well as how such information is organized. Another example of joint effort has been the adapting of the Standard to multiple languages. Restricting the character representation for data to a single byte also restricts representation of information in languages which have more than 256 characters. The Asian languages are good examples of ones which cannot be accommodated with a single byte. This problem is certainly not unique to WG VI and VIII, and they are considering the work being done by international standards organizations.

FUTURE DIRECTIONS

A technology-driven standard, such as any of the ACR-NEMA standards family, cannot be static if it would continue to be applicable to a large segment of the user community. Evolution of the ACR-NEMA standards was assumed by the Committee and WGs from the outset, and a mechanism for standards growth was outlined. For the parent Standard, a specific table of how new versions would connect to old (and vice versa) was developed. This compatibility statement is part of the opening section of Version 2.0 (ACR-NEMA 300-1988), and in summary states that the software for newer versions of the Standard should interpret incoming messages which were generated on earlier version systems with no difficulty. New groups, elements, or commands should not be expected to be present. Conversely, an earlier version system receiving a new version message will ignore new groups, elements, or commands. However, the new version must contain all the groups and elements mandatory in the earlier version. These princi-

ples have guided development of the Standards, and restrict how much the data dictionary of the Standard can be changed.

A major change to the philosophy of the parent Standard is being considered. This has been partially driven by WG VIII requirements, but has also been a constant request from users trying to implement the ACR-NEMA Standard. The change involves defining a level at which the Standard could be split. This horizontal cut through the Standard layers would be done so that different physical layers could be used with the ACR-NEMA data structure and upper-layer protocol. This had been done by several vendors and academic institutions, but is currently not an ACR-NEMA compliant methodology.

In all likelihood, the split would be made at a layer below which exist a number of ISO standard implementations. So far, the consensus is that the "logical" layers would consist of the current ACR-NEMA application, presentation, and session layers. The existing lower layers would be retained, probably as a separate standard, so that they would not be obsolete. In fact, these lower layers may (because of existing or prototype implementations) remain as a good choice when point to point connections (as between a piece of imaging equipment and a network interface unit) are required. For use over networks, however, other existing standards that more thoroughly address network connections may be superior. Connections between different computer systems, as are likely to be encountered in HIS/RIS/PACS interfaces, are another major area for use of such a "logical" ACR-NEMA standard. A reason that the ACR-NEMA hardware standard may remain useful is that using it forces much of the network protocol outside of the imaging equipment. Such protocol would be handled in a network interface unit, offloading the overhead from the imaging equipment computer. For some high performance network connections, requiring the host processor to handle the protocol could result in a tremendous increase in overhead, and would slow down performance of the host. While this solution is not likely to be the least costly, it can provide higher performance, and will allow retrofit to older imaging equipment for which dedicated high performance network interface board sets may not be available. The split of the

standard may also be difficult to implement if all existing specifications are to be met.

The Standard method of defining different packets for data and commands is one problem facing this split. This part of the ACR-NEMA protocol is in conflict with ISO-OSI practice. WG VI is considering solutions to this problem. Assuring that the vertical layer interfaces at the level of the split are ISO-OSI compatible, while retaining the ability to use the existing lower layer protocol, is another challenge facing the Working Group.

One of the very successful activities of WG VI in 1989 was to hold a workshop for implementers. This meeting resulted in a number of clarifications of the Standard as well as some proposed solutions for problems. The results of this meeting were published by NEMA and distributed to those who ordered copies of the Standard. A recent (May 21-23, 1990) hardware workshop was conducted in which six manufacturers (De Jarnette Research Systems, [Timonium, MD] General Electric Medical Systems, [Milwaukee, WI] Merge Technologies, [Milwaukee, WI] 3M, [St Paul, MN] Siemens Medical Systems, [Hoffman Estates, IL] and Vortech [Richardson, TX]) brought test hardware implementations of the Interface Standard to Georgetown University (Washington, DC), and tested all possible pairwise connections. Of 15 possible connections, all were successful in that bidirectional data exchange was demonstrated. In some instances, testing was successful up to the application layer of the Standard. The current activity of WG VI has been to form an ad hoc working group to iron out remaining differences in implementation interpretations so that future testing is likely to result in communication through the application layer for all who participate. It is anticipated by the members of this ad hoc group that such work will not take a long time, given the degree of success achieved in the first round of testing. For any manufacturer or institution who wishes to be included on the mailing list of this working

group, or who would be willing to participate in the next round of tests, the NEMA Staff Executive (David Snaveley (202) 457-1965) should be contacted.

CONCLUSION

The ACR-NEMA Standard and the family of related standards continues to grow and evolve. Though the Standard has come under some criticism, the ACR-NEMA Committee was bound to follow NEMA rules which eliminated some of the possibly easier alternatives from being used. The appearance of implementations from a number of vendors and institutions and the successful pairwise testing, however, have shown that the Standard can be built, and that it does work. As more institutions install PACS, the continued need for the ACR-NEMA standards has become apparent. This general growth of PACS is at least partially responsible for the continued requests for additions to the Standard, and will foster its evolution as PACS-wide (rather than point to point) interface.

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