

Profiles for medical image interchange

Committees responsible for this Published Document

The preparation of this Published Document was entrusted to Technical Committee IST/35, Medical informatics, upon which the following bodies were represented:

- Association of Anaesthetists of Great Britain and Ireland
- BCS Nursing Specialist Group
- British Computer Society
- British Computer Society (Health Informatics Specialist Groups)
- British Medical Association
- British Nuclear Medicine Society
- College of Radiologists (Clinical Oncology)
- Computing Services and Software Association
- Conference of Royal Colleges Information Group
- Department of Health
- Electro Medical Trade Association Limited
- Faculty of Public Health Medicine of the Royal College of Physicians in the UK
- Institute of Medical Laboratory Sciences
- Nine Tiles K-net
- Management Consultancies Association
- National Health Services
- NHS (Information Management Centre)
- Royal College of Surgeons of England
- Simpler Trade Procedures Board (Sitpro)
- Society for Computing and Technology in Anaesthesia

This Published Document, having been prepared under the direction of the Information Systems Technology Assembly, was published under the authority of the Standards Board and comes into effect on 15 May 1996

© BSI 1996

The following BSI references relate to the work on this standard:
Committee reference IST/35

Amendments issued since publication

Amd. No.	Date	Text affected

ISBN 0 580 25291 4

Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
Text of CR 12069	2

National foreword

This Published Document has been prepared by Technical Committee IST/35 and is identical with CR 12069 : 1995 *Profiles for medical image interchange* published by the European Committee for Standardization (CEN).

Compliance with a British Standard does not of itself confer immunity from legal obligations.

August 1995

English version

Profiles for medical image interchange

This CEN REPORT has been prepared by EWOS/EG PT024 for Technical Committee CEN/TC 251, Medical informatics, and has been approved by CEN on 1995-06-28.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

© CEN 1995 All rights of reproduction and communication in any form and by any means reserved in all countries to CEN and its members

CONTENTS

1.	INTRODUCTION	
1.1	Background	1-1
1.2	Contents of this ETG	1-1
1.3	Originators	1-2
2.	SCOPE AND METHOD OF WORK	
2.1	Scope	2-1
2.2	Method of Work	2-1
3.	REFERENCES	
4.	ABBREVIATIONS AND DEFINITIONS	
4.1	Abbreviations	4-1
4.2	Definitions	4-2
5.	CHARACTERISTICS OF MEDICAL IMAGING	
5.1	Legal and Regulatory Aspects	5-1
5.2	Kinds of Data Handled	5-1
5.3	Technical Aspects	5-2
5.4	Compression	5-2
5.5	Medical Imaging Modalities	5-3
6.	CURRENT WORK	
6.1	Relevant Standards and Specifications	6-1
6.2	Overview of General Imaging Standards	6-6
6.3	Overview of Medical Imaging Work	6-15
7.	SCENARIOS	
7.1	Introduction	7-1
7.2	User Scenario Characteristics	7-1
7.3	Taxonomy of Medical Imaging User Scenarios	7-3
7.4	Imaging Application User Scenarios	7-4
7.5	Derivation of User Scenario Characteristics	7-13
8.	PROPOSED TAXONOMY OF PROFILES FOR MEDICAL IMAGE INTERCHANGE	
8.1	Introduction	8-1
8.2	Transport Profiles	8-1
8.3	Application Profiles	8-2
8.4	Interchange Format and Representation Profiles	8-4
8.5	Combined A and F Profiles (H-Profiles)	8-6
8.6	Selected Profile Descriptions	8-6

9.	ATTRIBUTES FOR MEDICAL IMAGING	
9.1	Introduction	9-1
9.2	Attributes Determining Transport (T) Profiles	9-1
9.3	Attributes Determining Application (A) Profiles	9-2
9.4	Attributes Determining Format (F) Profiles	9-2
9.5	Attributes Determining Hybrid (H) Profiles	9-4
9.6	Attribute Values	9-5
10	DERIVATION OF THE MATRIX	
10.1	Introduction	10.1
10.2	Goodness of Fit Factors (GOFFs)	10-1
10.3	Assignment of GOFFs	10-3
11	THE MATRIX	
11.1	Introduction	11-1
11.2	Derivation of Sets of Attribute Values	11-1
11.3	The Matrix	11-3
12	DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS	
12.1	Discussion of Matrix Findings	12-1
12.2	Conclusions and Recommendations	12-3

1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Requirements for Medical Image Interchange

Traditional analogue medical imaging devices are fast being replaced by digital apparatus in hospitals. This, together with the increased use of information systems and communications in the healthcare environment, has led to an upsurge in demand for communication involving medical images. Over recent years technological restrictions have limited the demand for intercommunication but recent developments in both imaging equipment and information technology have to a large degree overcome these.

A wide variety of information technologies are being applied successfully in other industries to reduce cost and increase productivity and quality. Applying those technologies to healthcare services can help alleviate the tremendous pressure on the healthcare system.

In this situation standards are becoming increasingly important. Currently no international standards exist for medical image interchange, but development of standardised formats is underway in Europe, USA and Japan. Once application layer standards for medical image interchange are available, directions are needed on the use of these standards in conjunction with supporting communication standards. Wherever appropriate international standards exist these should be preferred in this connection. As yet, little work has been done on the OSI profiles necessary to allow communication and interworking using these standards.

1.1.2 The Joint EWOS / CEN Work Programme

In 1989, SOGITS issued Mandate BC-IT-SI-05 concerning medical informatics. This Mandate was split into two parts, one being the responsibility of CEN and the other of EWOS. As a result CEN / TC 251 and EWOS / EG MED were set up to undertake work that fell within the remit of CEN and EWOS respectively.

The CEN Work Programme consists of a number of work items and is being undertaken by seven Working Groups. One of these, WG 4, is responsible for medical imaging and multimedia. Elements of this work which involve OSI profiles are, however, being handled by EWOS.

The CEC issued a mandate in respect of work item 4.1, "Profiles for Medical Image Interchange", which is included as an Annex to this document. This mandate caused the formation of EWOS Project Team PTN024 which produced a report on medical image interchange profiles between May 1992 and August 1993. The PTN024 report was approved by EWOS TA in October 1993.

This EWOS Technical Guide is a revised and updated version of the PTN024 Report, rewritten so that it can be used as a guide to the use of communications profiles in the field of medical imaging.

1.1.3 Related Work

CEN/TC 251/WG 4 is in the process of drafting a set of ENVs collectively entitled MEDICOM (MEDical Image COMmunication). Similar work is being done by ACR-NEMA, a joint committee of the American College of Radiology (ACR) and the National Electronic Manufacturers Association. Version 3 of this standard is known as "Digital Image and Communications in Medicine (DICOM)".

1.2 CONTENTS OF THIS ETG

The areas addressed in this ETG are as follows:

- Survey of relevant work in the area of OSI profiles for image interchange
- Recommendations for European profiles

This was done by applying the method defined in the EWOS Technical Guide, "A Method for Defining Profiles for Healthcare" EWOS / ETG 021.

1.3 ORIGINATORS

This ETG has been produced by Martin Whittaker of Touchstone Consultancy Ltd.

The PTN024 Project Team, on whose work this ETG is based, consisted of the following members:

Leader	Rudy Mattheus
Team	Katrine Weisteen Bjerde Tony Kerr Martin Whittaker Norbert Lipszyc Louis Schilders Andrew Todd-Pokropek Marek Rejmer Rainer Thieme

Between them, members of the team represent the key parties concerned with the domain of medical image interchange: imaging equipment suppliers, communications specialists, imaging specialists, OSI experts, medical specialists and people with practical experience of implementing medical image communication systems.

2. SCOPE AND METHOD OF WORK

2.1 SCOPE

The purpose of this ETG is to give advice as to what profiles are suitable for applications concerned with multi-disciplinary medical image interchange.

Multi-disciplinary medical image interchange includes applications in radiology, nuclear medicine, pathology, internal medicine, dermatology, ophthalmology, etc. dealing with different types of images (e.g. static greyscale, colour, volumetric, time sequences etc.) all with dedicated user requirements.

The audience of the ETG includes users of medical imaging applications, standards bodies and implementors.

2.2 METHOD OF WORK

The ETG team applies the method defined in the EWOS Technical Guide 021 to the field of medical image interchange ("the Method"). It is strongly suggested that readers of this ETG familiarise themselves with this method before reading this report.

The steps taken to apply the Method were as follows:

- Review of the field of medical image interchange and derive the attributes and attribute values that affect the transmission of medical images
- Creation of a series of User Scenarios describing real-world medical imaging requirements
- Derivation of technical characteristics of these scenarios to enable each to be described exactly in terms of their communication requirements
- Selection of Transport Profiles, Application Profiles and Format Profiles relevant to medical imaging. Only these profiles which were candidates to support image interchange were considered, "Candidate Profiles".
- Establishment of taxonomies of Candidate Profiles and User Scenarios so as to allow them to be mapped on to each other in a rigorous manner.
- Derivation of the Profile Functional Characteristics (PFCs) for each communications profile
- Definition of the quality criteria to be used for the evaluation of the usefulness and appropriateness of each profile, known as Goodness Of Fit Factors (GOFFs).
- Production of a matrix of User Scenarios and Candidate Profiles, where each intersection in the matrix is a GOFF, i.e. an indicator of the suitability that Candidate Profile in the circumstances described in the User Scenario.
- Whenever the GOFF indicated that a no Candidate Profile would satisfy the user need, recommendations for the enhancement of the base profile were made.
- As a result of the mapping activities, a set of usable profiles could be defined. These profiles have been included in a summary sheet per scenario.

The recommendations at the end of this ETG give wherever possible the ideal set of profiles for a given user scenario. There may however be other sets of profiles which could be used to satisfy that scenario. There may also be other sets of profiles which do not completely satisfy the user requirements by, for

example, not allowing the image transfer within the time required by the user. This does not mean that the image cannot be transferred, only that it cannot be transferred in such a way as to satisfy completely the user requirement. This situation is common in case where the user scenario requires a very high bandwidth for which no profiles are currently available.

3. REFERENCES

- 1 Method for Defining Functional Profiles for Healthcare, EWOS Technical Guide 021.
- 2 Directory of the European Standardisation Requirements for Healthcare Informatics and Programme for the Development of Standards, Adopted on 1991-02-28 by CEN TC 251; Approved by CEN / BT, version 1.3.
- 3 First working document CEN TC 251 PT 006, " MEDICOM - Medical Image and Related Data Structure - overview and framework" version 1.0 - 1 June 93.
- 4 ACR-NEMA - Digital Imaging and Communications in Medicine (DICOM). ACR-NEMA Working group VI. 1992
- 5 Final Report of EWOS /EG MED/PT N 024, Profiles for Medical Image Interchange, 1993

4. ABBREVIATIONS AND DEFINITIONS

4.1 ABBREVIATIONS

ACR	American College of Radiology
ACSE	Association Control Service Element
ANSI	American National Standards Institute
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
AV	Attribute Value
CAI	Common Architecture for Imaging
CCITT	Comité Consultatif International Télégraphique et Téléphonique
CCR	Commitment, Concurrency and Recovery
CEC	Commission of the European Communities
CEN	Comité Européen de Normalisation
CEN TC 251	Technical Committee for Medical Informatics
CLNS	Connectionless Mode Transport Service
COTS	Connection Oriented Transport Service
CT	Computed Tomography
DF	Digital Fluoroscopy
DIS(1)	ISO Status (Draft International Standard)
ECG	Electrocardiogram
ED	EWOS Document
EDI	Electronic Data Interchange
EG MED	Expert Group Healthcare (EWOS)
ETG	EWOS Technical Guide
EWOS	European Workshop for Open Systems
GOFF	Goodness of Fit Factor
GP	General Practitioner (in medicine)
HIS	Hospital Information System
IA5	International Alphabet 5
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers (USA)
IIF	Image Interchange Facility
IMACS	Image Management and Communication System
IPM	Interpersonal Messaging
ISDN	Integrated Services Digital Network
ISO	International Organisation for Standardisation
ISP	International Standardised Profile
JPACS	Japanese PACS Society
MHS	Message Handling System
MRI	Magnetic Resonance Imaging
NEMA	National Electrical Manufacturers Association (USA)
OSI	Open Systems Interconnection
PACS	Picture Archive and Communication System
PC	Personal Computer
PET	Positron Emission Tomography
PFC	Profile Functional Characteristic
PIKS	Programmer's Imaging Kernel System
ppi	Pixels Per Inch
PSDN	Packet Switched Data Network
PSTN	Public Switched Telephone Network
PT	Project Team
RGB	Red, Green, Blue
RIS	Radiology Information System

ROI	Region of Interest
SAV	Set of Attribute Values
SC	Sub-Committee
SOGITS	Senior Officials Group - Information Technologies Standardisation
SPECT	Single Photon Emission Computer Tomography
TC 251	CEN Technical Committee on medical informatics
TR	Technical Report (ISO)
US	Ultrasound
WG	Working Group

4.2 DEFINITIONS

A-profile	Application profiles define the use of protocol standards from OSI layers 5 to 7, to provide for the structured transfer of information between end systems [ISO/IEC TR 10000-2]. A-profiles require connection-mode transport services.
Acquisition Unit	Particular device required for performing an imaging procedure.
Application service element	That part of an application entity which provides an OSI environment capability, using underlying services when appropriate [ISO 7498 : 1992] A set of functions that provide a capability for the interworking of application entity invocations for a specific purpose on a single application association.
Archive System	Archive is the process of long-term storage and organisation of data and documents.
Association control service element	An ISO defined application service element that handles the establishment and the termination of associations between peer application entities.
Attribute	A property of an instance of communication. An attribute has a value.
B- profile	As A-profile, but requiring connectionless-mode transport service.
Conformance	Static conformance: A statement of the requirement for support by an implementation of a valid set of features from among those defined by a standard. Dynamic conformance: A statement of the requirement for an implementation to adhere to the behaviour prescribed by a standard in an instance of communication.
Data unit	Information to be exchanged consisting of a structured set of attribute values directly or indirectly related to information objects. The value of each attribute in a data set is expressed as a data element.
Digitiser	A device that codes images or shapes into digital data

DIS	Departmental Information System
Examination	A procedure performed on a patient or on a sample taken from a patient for diagnostic or therapeutic purposes in response to a request
F-Profile	Interchange formats and character repertoires are defined as F-profiles and are in principle capable of being carried over any of the transfer services.
File	An ordered set of computer data (including programs), of arbitrary length, uniquely identified by a pathname.
Folder	A folder associates data objects that are related to a specific type of examination or to another grouping criterion.
GP	General medical Practitioner.
H-profile	Hybrid profile: a combination of F and A profiles
HIS	An system which in a hospital handles the data processing needs, including functions such as medical records storage and access, admissions/discharges/transfers, order communications etc. Parts of the Hospital Information System that are capable of handling images are also considered to be part of the IMACS.
IMACS	An system used in a healthcare centre for the storage and processing of images, for controlling access to stored and/or processed images, and for distributing these images to the users. Image Management And Communication System encompasses the entire PACS plus all image handling devices which are part of the HIS.
Image data	Data which is used to render a digital image. It includes pixel or voxel data and may include overlays, annotation and regions of interest.
Image related data	Data related to an image such as descriptive data, image associated data, examination related data etc.
Imaging department	A department producing images, either digital or analogue.
Interoperability	The ability of two or more systems to exchange information and mutually to use the information that has been exchanged.
Medical image	An image used for medical or healthcare purposes, either for treatment of a patient or research.
Message	An information object which contains address information and content [ISO 2382-27] Another source: (General) An ordered series of characters intended to convey information. (At the data level) The ordered sequence of data elements representing the information to be exchanged as one unit between an environment and an information system.

Object	A entity which has a state and a defined set of operations to access and modify that state. Objects can interact with one another. [ISO 7498]
Object class	A formal description of a set of objects possessing the same logical and properties. [ISO 7498-4] It includes a description of its purpose and the attributes its possesses. It does not include the values of these attributes.
PACS	A system is used for the storage and processing of images in an imaging department, enabling radiologists and imaging specialists to perform diagnostic tasks and select which images are needed by other non-specialist doctors.
Pixel	An area of defined shape, size and position within a two-dimensional image with which a measured value or values are associated.
Profile	A set of one or more base standards, and, where applicable, the identification of chosen classes, subsets, options and parameters of those standards, necessary for accomplishing a certain function. [ISO TR 10000-1]
Protocol	A set of rules and formats defining actions and responses exchanged between systems in order to provide services.
RIS	A Radiology Information System handles the data processing needs of a radiology department
Scenario	A scenario sets the scene in which some action is to take place. It is a formal description of a class of activities including the semantics of agreements, conventions and information content. [ISO/IEC JTC 1 N 1384]
Service class	A structured description of a service which is supported by co-operating application entities using specific commands acting on a specific class of objects.
T-profile	Transport profiles define the use of protocol standards from OSI layers 1 to 4, to provide the OSI Transport Service [ISO/IEC TR 10000-2]. T-profiles provide connection-mode transport services.
U-profile	As T-profile, but providing connectionless-mode transport service.
Voxel	A volume of defined shape, size and position within a three-dimensional space with which a measured value or values are associated.

5. CHARACTERISTICS OF MEDICAL IMAGING

Most imaging disciplines have special characteristics that make them different from other imaging disciplines. This section contains an overview of characteristics of medical imaging. Seen in isolation, most of these characteristics apply to more imaging disciplines than the medical one.

Characteristics of medical imaging may be divided into the following three main areas:

- Legal and regulatory aspects
- Kinds of data handled
- Technical aspects of the environment in which the images are used

Compression of medical images is treated in a separate section.

Finally an overview is given of the amount of data produced using the different imaging modalities currently used.

5.1 LEGAL AND REGULATORY ASPECTS

One of the most important characteristics of medical imaging is that the images are used in a context where people's health or even lives are at stake. As a consequence of this, a number of laws and regulations concerning the use of medical images exist. Legislation differs from country to country, but some of the main aspects are :

- **Ownership / responsibility**
In many countries legislation dictates that all medical images be preserved for a certain period of time (typically 5-10 years) before they can be deleted. In such cases it should be clear who is responsible for images not getting lost.
- **Access rights**
Who is allowed to look at, modify or delete an image? In some hospitals, only senior doctors are allowed to delete images. Others may be allowed to look at or copy them and yet others may not be allowed to access them at all.
- **Identification**
In clinical applications the ability to associate an image with the right patient is vital. For research purposes the opposite is often the case, i.e. anonymity is required.

5.2 KINDS OF DATA HANDLED

Some typical characteristics are :

- **Amount of data**
As is the case in most imaging disciplines, medical imaging involves large amounts of data. The size of individual images is not too big (current maximum 2 - 4 MByte), but sets of related images will normally be stored rather than individual images.
- **Multi-dimensional data**
The image data will often consist of more than two dimensions. Examples of multi-dimensional image data are :
 - Time series. Many medical imaging modalities produce time series of images rather than just single images
 - Multi-band images. An image in which more than one value is stored for each pixel is called a multi-band image. Examples of such images are :

- Colour images where three bands are used to represent colour (RGB or other colour space)
- A set of images of the same object acquired with different parameter settings. (At present, such sets are normally handled as a series of separate images, but for many applications it would be more efficient to treat them as one single multi-dimensional image)
- An image with several features actually recorded simultaneously. This is the case for instance with ultrasound colour doppler images where the average, maximum and variance of the blood velocity is recorded.
- 3-D imaging. Imaging devices capable of producing 3-D spatial image data exist, but are not yet in common use.

An efficient way of storing and handling such multi-dimensional data is desirable.

- **Sets of related images.**
Images are normally not acquired or stored as separate images, but as sets of images taken during an examination. A mechanism is needed for hierarchical construction of such sets.
- **Associated data**
In most cases a considerable amount of non-image data is stored with the image. In addition to information associated with any digital image (size, resolution, colour look-up tables etc.), data associated with a medical image includes items such as:
 - Identification information (e.g. patient id, examination id)
 - Patient demographic data (e.g. height, weight, age)
 - Patient orientation (e.g. what part of the body is shown, which way was the patient facing)
 - Acquisition parameters (e.g. equipment parameter settings)
 - Additional clinical data (e.g. blood pressure or ECG trace)
 - Results from analysis tools applied (e.g. area or volume of blood vessels)
- **Annotation.**
Image annotation (text, graphics, voice) is used extensively. It must be possible to display images both with and without annotation.

5.3 TECHNICAL ASPECTS

- **Compression**
Due to the large amounts of data involved, compression is an important issue in medical imaging. Depending on the context in which an image will be used, different degrees of compression will be accepted. In diagnostic use, only a small factor of compression is currently accepted in order not to lose diagnostic information. Compression is discussed further in section 5.4.
- **Heterogeneous environment**
A PACS must interconnect not only computers, but also different medical devices like CT, MRI, medical hardcopy units etc. In most cases this implies dealing with a highly heterogeneous multi-vendor environment.

5.4 COMPRESSION

There are two main classes of compression algorithms: lossless and lossy. In lossless compression the compressed image can be reconstructed to be identical in every respect to the original image. In lossy compression, information is lost in the process. The compressed image can therefore only be reconstructed to approximate the original image.

Human vision is the determining factor in much image processing. When viewing an image, the individual pixels are not perceived. Human perception has an effect on how images are displayed, printed, compressed and enhanced.

Medical imaging uses computers to enhance, for example, digital X-rays to help locate regions of interest, thereby enhancing the resulting human perception of the image. Machine vision, and the information content of many images, goes beyond the limit of human perception. In machine vision, the target of the image is a machine rather than a human. Machines can locate features in an image that are beyond human perception.

The purpose of compression is to reduce the amount of data for storage or transmission while maintaining visual integrity. The choice between lossy and lossless compression and between different degrees of lossy compression requires trade-offs between fidelity and transmission/storage efficiency. The degree of compression that can be accepted depends mainly on three factors; the context in which the image will be used, the modality used to acquire the image and the characteristics of the object depicted.

If an image is to be used for diagnostic purposes, compression must not destroy diagnostic information. On the other hand, if an image is presented only for casual viewing, lossy compression yielding reduced image size is preferred. The different imaging modalities give rise to images with different resolution and different degrees of noise. The risk of losing vital information when applying lossy compression is greater in a noisy image than in a noiseless one and greater in a low-resolution image than in a high-resolution one. The risk of losing information is of course also greater if the object depicted contains fine detail.

Lossy compression is most commonly used for compression of greyscale and colour resolution. For instance if an imaging device originally provides 10 bits greyscale resolution, reducing this to 8 bits means you can store each pixel value using one byte instead of two.

Current algorithms for lossless compression yield a maximum compression rate of 3-to-1. Most algorithms give only 1.5-to-1 or 2-to-1. Lossy compression of digital X-ray images has been reported to yield a compression rate of 10-to-1 without loss of diagnostic information.

When considering the use of compression for transfer of images, it is important to weigh the time and cost of implementing compression algorithms in real time. A compression board that does not provide real time compression can represent a severe bottleneck, especially when used with high-speed networks like FDDI.

5.5 MEDICAL IMAGING MODALITIES

This section gives an overview of medical imaging modalities and the typical amount of data produced by the different modalities.

Notation used :

1 K (as in Kbit) = 1024 bit (2^{10})

1 M (as in Mbit) = 1024 Kbit

5.5.1 Digitised X-ray and Computed Radiography (CR)

Plain film and computed (digital) radiography examinations currently constitute a large proportion of studies performed within a typical radiology department. Most studies are currently conducted with plain film (X-rays).

A typical uncompressed digital image of an original 14" x 17" analogue X-ray film requires 48 Mbits, assuming that a digitizer is used that provides a 2K x 2K pixels spatial resolution and 12 bit greyscale resolution. A 2K digitizer typically produces an image in about 1 minute. 4K x 4K x 12 bit resolution digitizers are being developed, giving an image size of 192 Mbit

CR technology uses a photostimulable phosphor image plate to produce digital images that normally contain 2K x 2K x 12 bits (48Mbits) of information, but may have 2.5K x 2K x 12 bits (60 Mbits). As CR technology is more widely be introduced, it may replace much of the plain film operation. At present, the processing of a CR plate takes about 2 minutes.

Whether digitised X-ray or CR is used, several reports have indicated that 2K x 2K x 12 bit resolution images provide adequate resolution for some diagnoses, whereas 4K x 4K x 12 bit resolution provides adequate resolution for most studies.

A plain X-ray or CR study consists of 2 - 4 images. If 1 minute is allowed for each image transmission, the bandwidth required is therefore an order of magnitude less than the 10MBit / sec of ISO 8802-3 (Ethernet) LANs.

5.5.2 Computed Tomography (CT)

A CT scan study typically contains between 20 and 120 images with an average of about 50. Typical spatial resolution is 512 x 512. Although the transmitted images normally have 16 bit greyscale resolution (total of 4 Mbits per image), only 12 bit of information are used by the radiologist. The CT scanner typically processes 2.6 head studies or 3 body studies per hour, giving a total average bandwidth requirement of 150 KBit/sec for head studies and 170 KBit/sec for body studies.

5.5.3 Nuclear Medicine (NM)

NM modalities provide static studies, dynamic studies, multigated acquisitions (MUGAs), single photon emission computed tomography (SPECT) and positron emission tomography (PET). Typical characteristics of studies using NM modalities are given in the table below.

Study type	Spatial resolution	Contrast resolution	Mean no. of images	Maximum no. of images
Static	128 x 128	8 or 16 bits	6	20
Dynamic	64 x 64	8 or 16 bits	50	180
MUGAs	64 x 64	8 or 16 bits	25	30
SPECT	64 x 64	8 or 16 bits	50	128
SPECT	128 x 128	8 or 16 bits	50	180
PET	128 x 128	16 bits	62	93

The input bandwidth requirements for these modalities do not exceed the 10MBit/sec of ISO 8802-3 (Ethernet) LANs in general. They are as high as 2 MBit/sec for a 30-frame per second 16 bit dynamic study and as low as 17.5 KBit/sec for static studies that have an inherent 1 to 3 minute delay for acquisition of enough scintillations to create an image. For SPECT and PET, multiple sets of images for immediate viewing may be sent.

5.5.4 Ultrasound (US)

Ultrasound studies in a radiology department are commonly made up of a subset of 20 to 25 static images from a full-motion ultrasound examination. Each still image typically consists of 512 x 512 x 8 bits (2 Mbit) of information.

Ultrasound studies in a cardiology department (echocardiography) typically contain more data because time-series of images are commonly stored. Typical spatial resolutions for 2-D tissue images are 128 x 512, 256 x 256 and 512 x 512, normally with a greyscale resolution of 8 bits. A cine series of 30 images may therefore contain as much as 60 Mbits. A typical study may contain 1 - 2 cine series plus 5 - 10 static images.

The most space- and bandwidth-consuming kind of studies are stress-echo tests that may contain from 8 to 20 cineloops. Currently, only subsets of selected images are stored, but if the whole study were to be stored, say with a resolution of 256 x 256 x 8 bits, this would require between 120 and 300 Mbits

The bandwidth requirements for Doppler spectrum data will typically be much less than for tissue data.

5.5.5 Magnetic Resonance Imaging (MRI)

There are typically between 20 and 200 images in an MRI study, with an average of about 80 images. Each image typically has a resolution of $512 \times 512 \times 16$ bits (4 Mbits). MRI studies usually consist of 5 sequences (each containing 4 to 40 images), each requiring about 9 minutes to complete, with a final processing time of 5 to 10 minutes for the last sequence. Once a sequence has been completed, it can be transmitted or viewed. Assuming the images are transmitted in a pipeline fashion, the required transmission speed of an MRI system providing 80-image studies (i.e. 16 images per sequence) is 121 KBit/sec per sequence.

5.5.6 Digital Fluoroscopy (DF)

In digital fluoroscopy, images with a resolution of $512 \times 512 \times 8$ bits (2 Mbits) are obtained from a sequence produced in a medical procedure. For digital angiography (DA) the image sequence is typically displayed at 30 images per second and for other DF modalities at about 6 images per second.

Digital angiography uses biplanar views, which include two 30-image per second sequences that are analysed simultaneously. Each study is either an 8-view or a 12-view study. In either case, either one or two biplanar views are required.

Because of the bandwidth and storage demand, most DF studies are limited to the selection, manipulation and storage of 2 to 20 images from a study. For example, digital angiography full-motion video (cine) demands 60 MBit/sec. A 7 - 10 seconds burst would generate 3.4 to 4.8 Gbits of data (435 to 614 MByte) for an 8-view study and 5 to 7.2 Gbits (640 to 922 MByte) for a 12-view study. To provide full-motion video, the network must therefore sustain the 60MBit/sec bandwidth while providing video quality or transfer the 3 to 8 Gbits on request within a few seconds.

Present digital radiography environments do not provide the cine facility. Rather, a few selected images are processed, leaving the rest of the image sequence on film or video tape.

5.5.7 Digital Photography

Normally only a few images, typically 1-5. Typical image size $256 \times 256 \times 8$ bits.

5.5.8 Other modalities

The list of modalities could be expanded with other modalities such as:

- Digitised documents
- Digital Subtraction Angiography (DSA)
- Endoscopy
- Mammography
- Microscopy
- Electron Microscopy
- Thermography
- Dentistry X-ray
- Video

5.5.9 Summary

5.5.9.1 Data Rates Required

Studies have shown that clinicians prefer to see studies appear at display workstations within 2 seconds of the images being requested.

Table 5.1 shows the data rates required to transfer the average and the maximum amounts of data for the different modalities mentioned earlier in this section within a time span of 2 seconds.

Table 5.1 Data rates required for transfer within 2 seconds

Modality	No. of images (mean - max)	Resolution	MBit/sec (mean)	MBit/sec (max)	MBit/sec (lossless compr)	MBit/sec (lossy compr)
Film/CR	2 - 4	2K x 2K x 12	64	128	32	9.6
CT	50 - 120	512 x 512 x 16	100	240	80	24
NM Static	6 - 20	128 x 128 x 16	0.75	2.5	0.8	0.25
NM Dynamic	50 - 180	64 x 64 x 16	1.56	5.6	1.9	0.56
NM MUGA	25 - 30	64 x 64 x 16	0.8	1.0	0.3	0.1
NM SPECT	50 - 180	128 x 128 x 16	6.25	22.5	7.5	2.25
NM PET	62 - 93	128 x 128 x 16	7.8	11.6	3.9	1.16
MRI	80 - 200	512 x 512 x 16	160	400	133	40
MRI Selected	5 - 10	512 x 512 x 16	10	20	7.3	2
US Radiology	20 - 75	512 x 512 x 8	20	75	25	7.5
US Cardiology	35 - 140	512 x 512 x 8	35	140	46.7	14
US Card.Stress	240 - 600	512 x 512 x 8	240	600	200	60
US Selected	5 - 10	512 x 512 x 8	5	10	3.3	1
DA	4	512 x 512 x 8	4	60	n/a	n/a
DF	2	512 x 512 x 8	2	12.3	n/a	n/a
Dig. Phot.	1 - 5	256 x 256 x 8	1	5	1.7	0.5

Notes:

In the columns for mean and max bandwidth, an integer number of bytes is assumed to be used for storage of one pixel, i.e. 8 bit pixels are stored using 1 byte (8 bits), 12 bit pixels are stored using 2 bytes (16 bits)

The columns indicating bandwidth after compression represent an optimistic 3-to-1 compression rate for lossless compression and a 10-to-1 compression rate for lossy compression. In addition, packing of pixels is assumed, i.e. pixels are assumed to be stored using only the number of bits listed in the resolution column (12 bit pixels are stored using only 12 bits etc.). This means that for 12 bit pixels, the 3-to-1 compression rate is increased to a 4-to-1 etc.

For US Cardiology, a maximum of 20 static images plus 4 cine series is assumed.

For DA a networked cine facility is assumed at 30 images per second.

For DF a display rate of 6 images per second is assumed.

The numbers in the columns for compressed images are based on the "max" uncompressed column.

n/a means "not applicable".

5.5.9.2 Data Volumes

Table 5.2 shows the actual average and maximum amounts of data for the different modalities.

The same notes apply as for table 5.1.

Table 5.2 Data volumes for the different modalities

Modality	No. of images (mean - max)	Resolution	Mbytes (mean)	Mbytes (max)	Mbytes (lossless compr)	Mbytes (lossy compr)
Film/CR	2 - 4	2K x 2K x 12	16	32	8	2.4
CT	50 - 120	512 x 512 x 16	25	60	20	6
NM Static	6 - 20	128 x 128 x 16	0.2	0.6	213	64
NM Dynamic	50 - 180	64 x 64 x 16	0.4	1.4	0.5	0.14
NM MUGA	25 - 30	64 x 64 x 16	0.2	0.25	0.08	0.02
NM SPECT	50 - 180	128 x 128 x 16	1.6	5.6	1.88	0.56
NM PET	62 - 93	128 x 128 x 16	1.9	2.9	0.97	0.29
MRI	80 - 200	512 x 512 x 16	40	100	33	10
MRI Selected	5 - 10	512 x 512 x 16	2.5	5	1.7	0.5
US Radiology	20 - 75	512 x 512 x 8	5	18.8	6.25	1.88
US Cardiology	35 - 140	512 x 512 x 8	8.8	35	11.7	3.5
US Card. Stress	240 - 600	512 x 512 x 8	60	150	48	15
US Selected	5 - 10	512 x 512 x 8	1.25	2.5	0.8	0.25
DA	4	512 x 512 x 8	1	15	n/a	n/a
DF	2	512 x 512 x 8	0.5	3.1	n/a	n/a
Dig. Phot.	1 - 5	256 x 256 x 8	0.2	1	0.33	0.1

5.5.9.3 Dimensionality and Content Types

Table 5.3 shows the dimensionality and the content types for the different modalities. By dimensionality we mean the number and kind of dimensions data produced by a certain modality will contain. Not all dimensions or all content types will be used in all examinations, but we assume that they will be used regularly enough to require the communication profiles to handle all dimensional and content types.

Table 5.3 Dimensionality and contents for the different modalities

Modality	Dimensionality	Content types	Relationship
Film/CR	2S	I,T	L
CT	3S	I,T	B
NM Static	2S	I,T	L
NM Dynamic	2S,T,B	I,T,W	C / B
NM MUGA	2S,B	I,T	B
NM SPECT	2S,T,B	I,T	B
NM PET	2S,T,B	I,T	B
MRI	3S,B	I,T	B
MRI Selected	3S,B	I,T	L
US Radiology	2S,T	I,T,W	B
US Cardiology	2S,T,B	I,T,W	B
US Card. Stress	2S,T,B	I,T,W	B
US Selected	2S,T,B	I,T,W	B
DA	3S,T	I,T	B
DF	2S,T	I,T	L
Dig. Phot.	2S,T	I,T	L

Notes:

The following values are used for dimensionality :

- S, 2S and 3S for 1, 2 and 3 spatial dimensions
- T if the data can be a time series
- B if spectral bands or colour bands can be used

The following values are used for content types :

- I for image
- T for associated text
- W for associated waveforms like ECG

The following values are used for relationships. Some modalities produce multiple images with a defined relationships between them (e.g. "slices through a head"). Further relationships are given in Table 9.4 and section 9.6.3.:

- N for none
- L for loose
- C for close
- B for both

Relationship is only applicable if there is more than one image.

6. CURRENT WORK

6.1 RELEVANT STANDARDS AND SPECIFICATIONS

The objective of this chapter is to survey existing standards and specifications which may be relevant to the storage, transfer and/or processing of medical images, and which may be considered as candidates for inclusion in standardised profiles. A list of such documents has been compiled using the following criteria:

- standards already widely used in the medical imaging community
- standards which have been proposed for use for transferring images in the medical or non-medical field
- standards applicable to general data formatting/transfer, potentially with the ability to handle medical images.

The list of standards and specifications is presented in the following tables according to the relevant layer(s) in the OSI/OSE reference model, as follows:

- Information Representation and Format Standards (F-Profiles)
- Applications (A- and B- Profiles)
- Transport protocols (T- and U- Profiles)

The list only includes "open" standards, i.e. those which have been published by a recognised international standards-making body or are freely available in the public domain.

Also, within each table, the referenced standards and specifications are divided into the following categories:

- Standards with Profile Entries in ISO TR 10000 Taxonomy
 - In these cases, standardised profiles may already have been defined which will match the requirements for medical imaging. The characteristics of the defined profiles therefore need to be examined.
- Other de jure Standards (including draft standards)
 - In these cases, no standardised profiles have (yet) been defined, or perhaps none are required if the base standard has only a few optional features. It may be necessary to define specific medical imaging profiles.
- De Facto Standards.
 - Such standards exist outside of the OSI/OSE reference model. They may be in widespread use and may need to be incorporated into profiles for medical imaging as an aid to OSI/OSE migration.
- Other Relevant Standards and Specifications.
- Such standards have a limited specialised scope and their use is not expected to be widespread outside of the medical imaging domain. Again, they may need to be incorporated into profiles for medical imaging as an aid to OSI/OSE migration.

TABLE 6.1 : Information Representation and Format Standards (F-Profiles)

STANDARDS WITH PROFILE ENTRIES IN ISO TR 10000 TAXONOMY	OTHER DE JURE STANDARDS (INCLUDING DRAFT STANDARDS)	DE FACTO STANDARDS	OTHER RELEVANT STANDARDS AND SPECIFICATIONS
ODA ISO 8613 Open Document Architecture and Interchange Format	CGRM ISO 11072 Computer Graphics reference model	TIFF Tagged Image File Format An industry standard for image storage	ACR-NEMA V2.0 Point-to-point transfer of radiology images
	Coded representation of pictures ISO 9281 A multi-part standard covering general methods of encoding pictures and text	GIF Graphics Interchange Format Public domain image file format widely used on bulletin boards	DICOM V3.0 Digital Imaging and Communications in Medicine (also known as ACR-NEMA V3.0). Specifies 3 alternative protocol stacks: Point-to-point (as ACR-NEMA V2.0); TCP/IP; OSI. Approved October 1993
	IPI ISO 12087, ISO 12089 Image Processing and Interchange, including Image Interchange Facility (IIF) and its encoding		DEFF Data Exchange File Format (also known as US-TIFF). Intended for ultrasound image transfer on magneto-optical media. The image file format is a superset of TIFF
	MEDICOM Standard for medical image communication currently being developed by CEN/TC251/WG4		Papyrus File format based on ACR-NEMA V2.0, developed at the University Hospital of Geneva
	CGM ISO 8632 Computer Graphics Metafile. Standard for geometric graphics		Interfile Interfile Version 3.3 has been defined by WG1 of the COST-B2 project, based on Report No.10 of the American Association of Physicists in Medicine (AAPM). It defines an intermediate file format for use in nuclear medicine. It uses a tagged file format, based on key-value pairs
	TIF.n CCITT Recommendation T.73 (1984) TIF.0 (Text Interchange Format 0) is used by Group 4 facsimile class 1 terminals. TIF.1 can be used by mixed-mode Teletex and Group 4 facsimile class 2 and 3 terminals		SPI Standard Product Interconnect. Interchange format for exchanging images between the proprietary architectures of Siemens and Philips. Based on ACR-NEMA V2.0

	EDIFACT ISO 9735 Character-based syntax standard. Could contain embedded image segments		IS&C Image Save and Carry Standard being produced by JPACS (Japanese PACS Society) to specify disk formats and medical data file formats to be used on magneto/optical discs. The image data format is based on ACR-NEMA V2.0
	JPEG ISO 10918 Standard for digital compression and coding of continuous-tone still images		
	JBIG ISO 11544 Standard for progressive bi-level image compression		
	MPEG ISO 11172 Standard for coding of moving pictures and associated audio for bit rates up to 1.5 Mbps		
	MPEG CD 13522 Standard for multimedia and hypermedia information objects		

TABLE 6.2 : Applications (A- and B- Profiles)

STANDARDS WITH PROFILE ENTRIES IN ISO TR 10000 TAXONOMY	OTHER DE JURE STANDARDS (INCLUDING DRAFT STANDARDS)	DE FACTO STANDARDS	OTHER RELEVANT STANDARDS AND SPECIFICATIONS
MHS ISO 10021 Message Oriented Text Interchange Service (MOTIS). Aligned with CCITT X.400. Store and forward messaging.	ROSE ISO 9072 Remote Operations Service Element: service and protocol. May be used to support applications which perform operations on image data	SMTP (RFC 821) Simple Mail Transfer Protocol. The Internet mail protocol	
FTAM ISO 8571 File Transfer, Access and Management	RDA ISO 9579 Remote Database Access. Includes SQL specialisation (ISO 9075). May be used for searching and retrieval of medical images	Telnet (RFC 854) Remote terminal access. Part of Internet suite of protocols.	
TP ISO 10026 OSI Transaction Processing	DTAM CCITT T.430 Document Transfer, Access and Manipulation. For handling ODA documents	SNMP (RFC 1157) Simple Network Management Protocol. Internet protocol for transferring information concerning managed objects. Uses UDP protocol.	
VT ISO 9041 Virtual Terminal		FTP (RFC 959) File Transfer Protocol. Part of Internet suite of protocols. Potentially usable for transferring image files between UNIX based systems	
CMIP ISO 9596 Common Management Information Protocol		Kermit Asynchronous file transfer protocol in the public domain. Listed in XPG/3 as protocol of choice for asynchronous file transfer	
Directory ISO 9594 The OSI Directory. Aligned with CCITT X.500		BLAST Public domain asynchronous file transfer protocol	
		X/modem, Y/modem, Z/modem Public domain asynchronous file transfer protocols	

TABLE 6.3 : Transport (T- and U- Profiles)

STANDARDS WITH PROFILE ENTRIES IN ISO TR 10000 TAXONOMY	OTHER DE JURE STANDARDS (INCLUDING DRAFT STANDARDS)	DE FACTO STANDARDS	OTHER RELEVANT STANDARDS AND SPECIFICATIONS
CSMA/CD ISO 8802-3 Carrier Sense Multiple Access with Collision Detection, LAN protocol commonly known as Ethernet	ISDN CCITT I-series Integrated Services Digital Network	TCP/IP (RFC 793/791) Transmission Control Protocol/Internet Protocol. Widely-used connection oriented transport protocol. Part of Internet suite. (Included in DICON V3)	
Token Ring ISO 8802-5 LAN protocol	B-ISDN (CCITT I-series) Broadband Integrated Services Digital Network for high-bandwidth communications	UDP (RFC 768) User Datagram Protocol. Connectionless transport protocol. Part of Internet suite.	
Token Bus ISO 8802-4 LAN protocol	CCITT V-Series Low level interfaces / protocols for modems used over leased or switched lines (e.g. V.42)	MNPx Microcom Networking Protocols Public domain protocols for error detection/correction and compression in modems	
Packet Switching ISO 8208 X.25 packet level protocol for Data Terminal Equipment	DQDB Distributed Queue Dual Bus ISO 8802-6 High speed LAN protocol.	ATM Asynchronous Transfer Mode Standards for high speed data transmission over reliable media	
FDDI ISO 9314 Fibre Distributed Data Interface (Metropolitan Area Network)			

6.2 OVERVIEW OF GENERAL IMAGING STANDARDS

This section considers those standards and specifications from the above list which are relevant to digital image interchange in general, and which may be considered as candidates for use in the specialised medical imaging domain.

6.2.1 Standard Model and Framework for Imaging

The Computer Graphics Reference Model (CGRM) specified in ISO/IEC 11072 provides a conceptual framework for the whole domain of computer graphics, which is defined as the creation of, manipulation of, analysis of, and interaction with pictorial representations of objects and data using computers. The CGRM defines a structure within which current and future standards for computer graphics can be compared and their relationships described. The relationship of computer imaging to the general CGRM is explained in an informative annex. It is anticipated that at some point in the future a more refined Computer Imaging Reference Model (CIRM) will be developed as a separate ISO standard.

ISO 9281 is a two-part standard under the general title Picture Coding Methods. Part 1 deals with identification methods for coding of pictorial information in digital form, and Part 2 specifies the corresponding registration procedure. Techniques are provided to switch between picture coding methods as well as to switch between the picture coding environment and byte-oriented coding systems for characters and control functions. The standard does not specify the contents of the data field of a picture entity. For instance, this field may also contain audio and/or animation data associated with the data specifying the pictures.

6.2.2 Image Processing and Interchange (ISO/IEC DIS 12087)

IPI is a standard for general image processing and interchange now under development within the ISO/IEC group on Computer Graphics and Image Processing (ISO/IEC JTC 1/SC 24/WG 7).

IPI is a three-part standard :

- Part 1, a Common Architecture for Imaging (IPI-CAI), describes the common architectural material on which the entire standard is based
- Part 2, the Programmer's Imaging Kernel System (IPI-PIKS) Application Program Interface (API), defines image processing operations to be carried out on images and their associated data
- Part 3, the Image Interchange Facility (IPI-IIF), defines a data format for the interchange of images between applications (the IIF-DF), and a set of routines for parsing and generating this format (the IIF Gateway).

The IPI-PIKS and the IPI-IIF may be implemented and used separately.

The IPI-IIF does not specify any protocol for the communication between systems, only a format to be used in the communication.

The data types within IPI are divided into three groups :

- basic data types (bit, Boolean, integer etc. and also arrays, lists etc. of such data)
- image data types (derived from basic data types)
- derived non-image data types (annotation, histograms, regions of interest, etc. derived from basic data types)

One of the main differences between existing image formats and IPI is that many of the existing formats have a 2-D image as the basic image element, whereas an IPI Elementary Image is an n-dimensional image. In IPI-IIF the number of dimensions is unlimited, whereas PIKS limits the number of dimensions to 5. These may for instance be used to represent 3-D volume, colour and time, or 3-D volume, spectral bands and time. Such an architecture will allow for more efficient processing of time series of images, for example. Simpler images will use fewer dimensions. The bands within an elementary image may have different resolution and different size.

A Compound Image data type is provided to allow large sets of related images and non-image data to be grouped hierarchically.

IPI supports two kinds of Derived Non-image data types. These are image annotation data (e.g. textual, graphic, audio tracks of motion pictures) and image-related data types (e.g. look-up tables, histograms, regions of interest (ROI)).

The IPI standard is intended for use in a wide variety of environments where digital images are handled. It has been developed to conform to other ISO standards in the same domain (including JBIG, JPEG and MPEG compression standards, the OSI reference model and the ODA content architecture framework). Those aspects of IPI that are concerned with the acquisition and display of digital images conform to the requirements of the CGRM.

The IIF-DF is a data format for exchanging arbitrarily structured image data. The IIF-DF is specified in terms of syntax entities which are each described using ASN.1 syntax together with a text description of the associated semantics and constraints, if any. For the encoding of IIF data types the ASN.1 Basic Encoding Rules are employed.

The standard distinguishes two kinds of profiles for the IIF-DF:

- conformance profiles, which specify a certain level of conformance that needs to be supported by an information processing system which conforms to the standard. Four different conformance profiles are specified:
 - a) **Full profile of the IIF-DF:** This profile fully supports the whole IIF-DF. No further constraints are stated. The profile is a true superset of the other profiles.
 - b) **Full PIKS profile of the IIF-DF:** This profile fully supports all image data objects that can be processed by means of the IPI-PIKS. With regard to data structures, this profile conforms to the PIKS technical profile. This profile is a true superset of profiles c) and d).
 - c) **Colour Image Profile of the IIF-DF:** This profile meets the requirements of colour image and greyscale applications. With regard to data structures, this profile conforms to the PIKS foundation profile. This profile is a true superset of profile d).
 - d) **Boolean image profile of the IIF-DF:** This profile provides the Boolean image structures applicable to certain areas of document processing, such as facsimile transmission.
- application profiles, which fulfil the needs of certain application domains. The standard does not include the specification of application profiles, but gives guidelines as to how such a profile may be defined for a particular user domain such as medical imaging.

Within the IIF-DF, compressed images may be specified and interchanged. For this purpose, IPI-IIF refers to the following standards:

- Facsimile Group 3 (CCITT T.4:1988)
- Facsimile Group 4 (CCITT T.6:1988)
- JBIG (ISO/IEC DIS 11544:1992)
- JPEG (ISO/IEC DIS 10918:1991)
- MPEG (ISO/IEC DIS 11172:1992)

Image data streams that conform to the encoded representation of compressed image data specified by these standards may be included in the IIF-DF. The encoding and decoding of these data streams is described within these referenced standards. The IIF-DF allows the description of images that contain compressed parts in combination with uncompressed parts. It is also possible to use multiple compression methods within a single IIF-DF conformant image.

The IIF-DF has been defined so that it could be used as an image content architecture for ODA.

6.2.2.1 Encoding for the Image Interchange Facility (ISO/IEC CD 12089)

This standard is being developed by the ISO/IEC JTC1/SC24 committee to define the encoding rules which shall apply to the representation of IIF image data. This enables the syntactic and semantic description of the IIF data format in ISO/IEC DIS 12087-3 to be independent of encoding rules and transfer syntaxes. The draft currently refers to the ASN.1 Basic Encoding Rules (ISO 8825), though other encoding rules such as the ASN.1 Packed Encoding Rules may be supported in the future. The encoding methods describe how to interpret the data contained in the elementary ASN.1 type OCTET STRING when this elementary type is used to encode a field of pixel values. Thus the CD 12089 encoding rules supplement the standard ASN.1 encoding rules.

6.2.3 ODA Raster Graphics Content Architecture (ISO 8613-7)

ISO 8613 (Open Document Architecture and Interchange Format) defines a standard interchange encoding for the structure and content of documents. A document may be encoded using the Open Document Interchange Format (ODIF), which contains the document content, together with layout and/or logical structure information. The document content in turn consists of a number of objects, each encoded according to a recognised Content Architecture standard. Currently defined Content Architectures include Character, Raster Graphics and Geometric Graphics. Simple (bi-level) bit-mapped images may be included in an ODA document using the Raster Graphics Content Architecture which is specified in Part 7 of the ODA standard (ISO 8613-7).

The raster graphics content architecture is defined by reference to the Group 3 and Group 4 facsimile transmission standards (CCITT Recommendations T.6 and T.4, respectively). A simple default 'bitmap' encoding is also defined, which in most cases occupies more space because data compression techniques are not used in this case.

Raster graphics is a general technique for representing an image as a series of rows of discrete pixels, or in ODA terms, in the form of picture elements known as 'pels'. The colour or darkness of each pel is given by a numerical value. A one-bit pel is either 'on' or 'off'.

An image of this type consists of a two-dimensional array containing many thousands of pels. The spacing of pels, when imaged, determines the resolution of the image.

This type of content is used to represent bit-mapped computer images (typically 150 or 300 pels per inch) or facsimile images (200 or 400 ppi). The basic measurement unit of 1/1200 of an inch is deliberately chosen as a multiple of both resolutions to enable both types of image to be incorporated into ODA-encoded documents.

Often, only a part of the pel array is used for imaging - especially where a scaling factor is in use or where there are layout constraints on the allowable or required image size. In this case a clipped pel array (being a subset of the full array) is used in the imaging process.

Each image text unit contains one image; currently in monochrome only.

Raster graphics content may be present in an ODA representation of a document in one of two forms: either formatted or formatted-processable form.

Formatted raster graphics content has been subjected to a layout process. It consists of a formatted pel array, with all required layout presentation attributes and positional information specified. This type of content is only suitable for input to an imaging process and enables the content of a document to be represented in a form such that it may be rendered (displayed or printed) as intended by the originator.

Formatted-processable raster graphics content has also been subjected to a layout process. It consists of a similar pel array, together with both logical presentation attributes and layout constraints. Positional information and layout presentation attributes are also included. This form of content may be edited, formatted or imaged as intended by the originator.

The raster graphics content architecture defines a number of presentation attributes which may influence either the content layout process or the content imaging process, or both. These presentation attributes may be used in basic object descriptions of the specific logical and specific layout structures, or in presentation styles, provided the attributes used conform to the type of content being described. The presentation attributes include:

INITIAL OFFSET: This attribute specifies the horizontal and vertical position of the initial point, relative to the reference point (normally the top left-hand corner) of the basic layout object in which the image is being laid out.

IMAGE DIMENSIONS: This attribute specifies the intended dimensions of the basic layout object that is to contain the image. It may be given in one of several ways, depending upon whether the image dimensions are to be width-controlled, height-controlled, area-controlled, or automatic. A preferred width and preferred height may be specified. With varying height and width, the aspect ratio may be affected. Another parameter enables the aspect ratio of the image to be fixed or variable.

PEL SPACING: This attribute specifies the spacing between successive pels and determines whether the fixed dimension or scalable dimension content layout method is used.

SPACING RATIO: This attribute determines the ratio between the pel spacing and the line spacing. From the definition of pel spacing, this attribute effectively determines the vertical distance between (lines of) pels.

NUMBER OF LINES/PELS PER LINE: These attributes specify the number of lines of pels in a content portion and the number of pels per line that are present in the content portion.

CLIPPING: This attribute determines, by means of two pairs of co-ordinates, the sub-region of the pel array, as described in the content portion, which is to be considered by the content layout process and the content imaging process. Where clipping is specified, only the areas of the clipped pel array will be imaged on the presentation medium. On later re-formatting, because a content portion will include the complete pel array, a different area of the image may be chosen. Effectively, this provides a mechanism for 'cropping' images to suit various purposes.

6.2.4 JPEG (ISO/IEC DIS 10918)

This standard, 'Information technology - Digital compression and Coding of Continuous-tone Still Images,' was prepared by the Joint ISO-CCITT Photographic Experts Group (JPEG) (JTC 1/SC 29/WG

10). Both the committee and the standards it has developed continue to be known informally by the name JPEG.

It is a two-part standard. Part 1 defines requirements and guidelines, and Part 2 defines compliance testing requirements.

It is applicable to non-moving greyscale or colour image data. It is applicable to a wide range of applications which require the use of compressed images. It is not well suited to bi-level image data.

The JPEG specification:

- specifies processes for converting source image data to compressed image data
- specifies processes for converting compressed image data to reconstructed image data
- gives guidance on how to implement these processes in practice
- specifies coded representations for compressed image data.

It does not specify a complete coded image representation. Such representations may include certain parameters such as aspect ratio and colour space designation, which are application-dependent.

It specifies two classes of encoding and decoding processes, lossy and lossless. The lossy processes are based on the discrete cosine transform (DCT) and allow substantial compression to be achieved while producing a reconstructed image with high visual fidelity to the encoder's source image. JPEG is very effective at lossily-compressing colour images at up to 30:1 compression ratios and higher. Extended DCT-based processes are capable of supporting progressive (as with JBIG) as well as sequential presentation. The progressive mode of operation works either by ordering bit-planes according to their significance or by ordering DC coefficients according to their significance. In the lossy mode, 8 and 12 bits per pixel are allowed.

The Lossless process uses a predictive process which is not DCT-based and can code from 1 to 16 bits per pixel.

A hierarchical mode of operation is provided, in which the image is encoded as a pyramid of different resolutions.

JPEG is one of the compression standards explicitly supported by the IIF-DF defined in the IPI standards. It is also the compression standard selected by DICOM V3.0 for lossy and lossless image compression.

6.2.5 JBIG (ISO/IEC DIS 11544)

This standard, 'Information technology - Coded representation of picture and audio information - progressive bi-level image compression,' was prepared by the Joint ISO-CCITT Bi-level Image Experts Group (JBIG) (JTC 1/SC 29/WG 9). It defines a method for lossless compression of a bi-level image, which can also be used for coding greyscale and colour images with limited bits per pixel.

The method is bit-preserving, which means that it is distortionless and that the final decoded image is identical to the original.

The method has a 'progressive' capability, which means that an image can be transmitted by first sending the compressed data for a reduced-resolution version of the image and then enhancing it as needed by transmitting additional compressed data, which builds on that already transmitted. This has two main advantages:

- it is possible to design an application with one common image database that can efficiently serve output devices with widely different resolution capabilities

- it is possible to implement a rapid browsing capability using relatively low bandwidth links, as a low resolution rendition is transmitted and displayed rapidly, followed by as much resolution enhancement as desired. The user can interrupt the transmission at any time.

The JBIG specification can be used for the lossless encoding of greyscale and colour images by encoding bit-planes independently as though each were itself a bi-level image. This approach can be used as an alternative to the lossless mode of the JPEG specification. For greyscale images up to 6 bits-per-pixel, JBIG may have a compression advantage over JPEG.

On scanned images of printed characters, observed compression ratios from 1.1 to 1.5 times as great as those achieved by the MMR encoding algorithm (which is less complex) described in CCITT Recommendations T.4 and T.6 have been achieved. On images with greyscale rendered by half-toning or dithering techniques, compression ratios from 2 to 30 times as great have been observed.

JBIG is one of the compression standards explicitly supported by the IIF-DF defined in the IPI standards.

6.2.6 MPEG (ISO CD 11172)

This is a standard for the coding of moving pictures and associated audio for bit rates up to 1.5 Mbps. It was prepared by the Joint ISO-CCITT working group JTC 1/SC 29/WG 11, known as MPEG.

The MPEG compression standard has been designed for synchronised video and audio compression. The compression ratio is about 100:1 with resulting video quality approximating that of a VHS video cassette player. In contrast to JPEG, the MPEG standard defines a colour mode (Y,C_b,C_r) and a fixed sub-sampling ratio among the three bands (4:1:1). Besides the DCT-based encoding of frames, the MPEG algorithm performs motion compensation (based on prediction, interpolation and the use of motion vectors) to achieve the high compression ratio. Three types of pictures are used: intra-pictures, interpolated pictures and predicted pictures. The encoding scheme is asymmetrical: the encoder is much more complex than the decoder. The MPEG audio signal is compressed into a size of about 192 or 384 kbps. The decompressed audio signal is in high fidelity stereo.

MPEG is one of the compression standards explicitly supported by the IIF-DF defined in the IPI standards.

6.2.7 MHEG (ISO CD 13522)

This is a developing standard for multimedia and hypermedia information objects. It is being developed by the Joint ISO-CCITT Experts Group JTC 1/SC 29/WG 12, known as MHEG.

6.2.8 TIFF (Tagged Image File Format)

TIFF is an industry standard for image storage originally developed by the Aldus Corporation. It supports bitmap graphics, including grey-scale and colour. It has become a de facto standard format for PC-based drawing and desktop publishing packages. The specification of TIFF 5.0 is published jointly by Aldus and Microsoft, in conjunction with leading scanner vendors and other interested parties. Many image-handling packages provide import and export in TIFF format.

TIFF is the format in which scanned images are most commonly saved. Some scanners can compress monochrome TIFF images by as much as 75%. TIFF files can be created at any resolution and can have any number of grey scales or colours. The disadvantages are that they can be very large in size, and that a large number of variants have been defined, using customised tags; TIFF needs to be profiled to ensure interoperability (e.g. see DEFF below).

6.2.9 GIF (Graphics Interchange Format)

GIF is a public domain image file format developed by CompuServe. GIF was developed to utilise the latest developments in video display hardware (e.g. VGA cards). It is very open-ended and contains many hooks for future development. GIF files are essentially device-independent, but if a GIF file is encoded, say, with more colours than a device is capable of displaying then the result will generally be unsatisfactory. Most of the available programs that utilise GIF files are shareware or public domain software. A large number of GIF image files is available in the public domain.

A GIF file may contain one or many images. The structure of the GIF file header varies with the image(s) that the file contains. The header contains both global data, which refers to all the images in a file, and local data, which only pertains to a particular image. A GIF image can contain up to 256 colours (which is the maximum number of colours that a VGA card can display simultaneously). A GIF file can define its 256 colours from a palette of sixteen million.

Images encoded using GIF may have their raster lines interlaced, so that when the image is transmitted, it can be built up progressively by the recipient. GIF encoded files use a lossless compression algorithm which is a modified form of the LZW (Lempel-Ziv and Welch) algorithm.

6.2.10 CCITT Interchange Formats

CCITT Recommendation T.4 (1988), 'Standardisation of Group 3 facsimile apparatus for document transmission,' defines a binary image format for use over the PSTN. The method is bit-preserving, which means it is distortionless and that the final decoded image is identical to the original.

CCITT Recommendation T.6 (1988), 'Facsimile coding schemes and coding control functions for Group 4 facsimile apparatus,' also defines a binary image format for use over the PSTN. Like Recommendation T.4, the method is bit-preserving.

Group 3 and Group 4 facsimile are lossless bi-level (or binary) compression standards. They work according to one- and two-dimensional, respectively, entropy coding schemes which were designed to perform best on a set of test images which have been scanned at approximately 200 dots per inch. They are sequential in nature because they compress and decompress images in a raster-scan order. The compression ratio achieved is image data-dependent. Both standards are included among the compression standards explicitly supported by the IIF-DF defined in the IPI standards.

CCITT Recommendation T.73 defines two Text Interchange Formats, TIF.0 and TIF.1. TIF.0 is used by, and used to communicate with, Group 4 facsimile class 1 terminals. In X.400 (1984), a 'TIF0' body part (type 4) represents a final form of document whose structure is defined in T.73 and which conforms to TIF.0 application rules. The body part contains a sequence of protocol elements describing the layout of a document. In X.400 (1988), the equivalent body part type is G4Class1BodyPart.

TIF.1 (Text Interchange Format 1) is the text interchange format defined in CCITT Recommendation T.73 (1984) which can be used by mixed-mode Teletex and Group 4 facsimile class 2 and 3 terminals. In 1984 X.400, a 'TIF1' body part (type 11) contains a document whose structure is defined in T.73, and which conforms to TIF.1 application rules. In the 1988 CCITT Recommendations, T.73 is obsolete, and the equivalent X.400 (1988) body part type is MixedModeBodyPart. A body part of this type represents a final-form document that is processable by the above terminal types. It comprises a sequence of protocol elements which describe the document's layout structure.

6.2.11 MHS

ISO 10021 (Message Oriented Text Interchange Service (MOTIS)) is aligned with the CCITT X.400 Recommendations for store and forward messaging. A number of message content types are defined, including:

- Interpersonal Messaging service, which defines a number of body part types, some of which may be used to convey image data
- EDI messaging service (CCITT X.435), which defines a mechanism for transferring EDI Interchanges, which may include binary image segments.

6.2.12 FTAM

ISO 8571 specifies OSI standards for File Transfer, Access and Management. Medical images can be transferred as unstructured binary files (standard document type FTAM-3), or a specialised document type could be defined.

6.2.13 OSI Transaction Processing

ISO 10026 specifies OSI standards for Transaction Processing models, services and protocols. TP may be used for image requests and transfers where TP properties such as atomicity, commitment and roll-back are required. The TP standard itself does not define a data transfer protocol other than a simple default Unstructured Data Transfer (UDT) protocol; it is designed rather to be used in conjunction with a user application service element (U-ASE) such as Remote Procedure Call (RPC) or Remote Database Access (RDA) standards, or a proprietary protocol. The U-ASE is responsible for the transfer of user data.

6.2.14 OSI Virtual Terminal

ISO 9040 and 9041 are the OSI standards for Virtual Terminal models, services and protocols. VT profiles may be useful in medical imaging for screen-based image displays.

6.2.15 Systems Management model

ISO 9595 and 9596 specify the OSI Common Management Information Service and Protocol (CMIS and CMIP). CMIP profiles could be used to support the manipulation of Medical Image Objects, as has been suggested within the IEEE MEDIX programme.

6.2.16 Directory model

ISO 9594 is a multi-part standard which specifies the OSI Directory; it is aligned with the CCITT X.500 Recommendations. Medical Images could be stored in an hierarchical Directory structure and retrieved using the Directory Access Protocol.

6.2.17 Remote Database Access (RDA)

RDA could potentially be used as the basis for searching remote image databases and retrieving selected images. The RDA service and protocol are part of the application layer of the OSI reference model.

ISO DIS 9579-1 defines a service interface which can be used in a variety of Database Management System (DBMS) environments. This generic service needs to be specialised for specific DBMS environments through the development of a supplementary standard.

ISO DIS 9579-2 defines a specialisation of the generic RDA service interface for a Structured Query Language (SQL) environment. SQL, a relational database language which allows for the definition, access and maintenance of a relational DBMS, is defined in ISO 9075.