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# Adopting the DICOM standard for medical infrared images

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*Abstract*— **In recent years there has been a resurgence of interest in the application of infrared thermal imaging in medicine. Yet fairly little effort has been spent towards standardisation of the field and a common communication and exchange format for thermal images. Most other medical areas where digital imaging is employed have subscribed to DICOM (Digital Imaging and COmmunication in Medicine) as a common standard for storing and retrieving medical imagery. In this paper we investigate how the DICOM standard in its current form can be adopted to store and communicate medical infrared images.**

**Keywords: infrared imaging, thermal imaging, thermography, DICOM, PACS, standard**

## I. INTRODUCTION

Advances in camera technologies and reduced equipment costs have lead to an increased interest in the application of infrared imaging in the medical fields [1]. Medical infrared imaging uses a camera with sensitivities in the infrared to provide a picture of the temperature distribution of the human body or parts thereof. It is a non-invasive, radiation-free technique that is often being used in combination with anatomical investigations based on x-rays and three-dimensional scanning techniques such as CT and MRI and often reveals problems when the anatomy is otherwise normal. Computerised image processing and pattern recognition techniques have been used in acquiring and evaluating medical thermal images [4] and proved to be important tools for clinical diagnostics.

Medical infrared images are captured and stored in digital form. Various camera suppliers are competing for their share in the market of medical infrared imaging. Unfortunately, each of these also store the captured images in their own, proprietary file format. This fact makes it hard to impossible to share thermograms between users of different systems, despite the urgent need for this facility in the light of increase of telemedicine and other emerging technologies. Thermal imaging packages such as CTHERM [4] allow the capture from various types of cameras and store images in a simple common format, yet this approach is only a step towards a suitable solution.

What is needed is a recognised standard for storage and interchange of thermograms. Unfortunately, so far very little effort has been spent to contribute towards such a standard (despite standardisation proposals in other areas of thermal imaging [5]). Clearly this standard needs to be supported by suppliers of both cameras and software packages. Most importantly such a standard must support the preservation of the original radiometric information. What this also means is that it must support a variety of spatial and radiometric resolutions both of which vary from camera model to camera model. Apart from the storage of the actual image information in digital form, a useful standard format will provide various other properties. Study identification and patient information as well as information on the clinicians and treatments should be supported as well as the addition of other items deemed useful for interpreting the thermogram.

Looking at other medical fields that deal with storage and exchange of digital images, DICOM (Digital Imaging and Communication in Medicine) [3], [2] has emerged as the major standard and is in common use for many imaging modalities such as MRI or CT scans. In this paper we investigate and propose how DICOM can be adopted for storing and communicating thermal medical images. Encouragingly, as will be made clear, most features that are required are already part of the current DICOM standard and only some some additional information need to be added separately. For the infrared imaging field this in turn will open the door widely to a wealth of support and tools for DICOM based imagery while at the same time significantly improving the way clinicians can manage and exchange thermograms.

The rest of the paper is organised as follows: The next section gives an introduction to the DICOM standard and the structure of DICOM images. Section III then contains our proposal on how to adopt DICOM for medical infrared imaging. An example of a thermogram converted to DICOM is provided in Section IV while Section V concludes the paper.

## II. THE DICOM STANDARD

There has been an enormous increase in the use of digital systems in the medical field over the last two decades. Nowadays, it is common in hospitals and other medical institutions to store, manage, exchange and retrieval medical images in a networked environment in so-called Picture Archiving and Communication Systems (PACS). PACS specify some agents, or nodes, that interact between them, allowing acquisition, visualisation, archiving, retrieving, communication and general handling not only of the medical images themselves but also their related information. It follows then that in such a system there is a need for a common standardised ”language” to which all nodes adhere so that effortless communication and collaboration is possible. This

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needed standardisation is given by the Digital Imaging and COmmunication in Medicine (DICOM) standard [3], [2].

DICOM mainly covers two main aspects: communication and data structures for storage. The communication aspect covers the definition of a protocol between PACS nodes based on the TCP/IP networking protocol and hence enables the agents to exchange information in a uniform and ordered manner. The data structure aspect defines the structure and formats of medical images and related information and is the part that we need to evaluate for its compatibility with thermal imaging.

DICOM files consist of two parts, headers and data. The headers specify the meaning of the data in the rest of the file and are organised in a tag-like fashion. These tags are called Information Object Definitions (IODs) and are divided into several groups according to their meanings. Each DICOM file must contain a Unique IDentifier (UID) used for unambiguous identification and a series of mandatory IODs; other IODs can be included optionally. Each of the IODs has a well defined meaning, for example those in group 8 contain information about the examination and the modality (e.g. MRI or x-ray), group 10 patient information (such as patient name, sex etc.) while group 28 defines the actual image data. Various bit-depths, arbitrary image sizes and several data representation schemes are supported as are several compression standards to reduce bandwidth and storage space. All the attributes that are defined in the standard documents comprise the public part of a DICOM file, additional - so-called private - attributes can be used by manufacturers or processing software to store further information though likely these will not be interpretable by other PACS nodes.

## III. ADOPTING DICOM FOR MEDICAL INFRARED IMAGING

The aim of this paper is to investigate how applicable the DICOM standard is for storing and exchanging medical infrared images and how it can be adopted as a standard to be used in the thermography field. Clearly, having such a standard has many advantages as it eliminates the need for various image capturing and interpretation software that are typically linked to a particular file format. Furthermore it will put a certain pressure on manufacturers each of which currently have their own, proprietary image file format. Finally, it would provide a uniform way of not only communicating the images themselves but also of additional information such as lab conditions, patient data and information supporting medical diagnosis and reporting.

Looking at the current version of the DICOM standard [3] we can see that for IOD (0008,0060) there is actually a modality type TG defined for thermography. However, no additional information is included in the standard on how this type of images is to be stored and interpreted. Clearly of most importance is the preservation of the original radiometric information. As thermograms are captured in digital form this is in fact easily accomplished. DICOM supports storing images in virtually any bitdepth (precision) hence preserving the original thermal resolution is guaranteed. Arbitrary image sizes are also supported and hence maintaining the original spatial resolution is also ensured.

In the following we cover in some detail the various aspects of our proposal of an infrared DICOM file.

### A. Image data

Obviously the most important aspect is the image data itself. As mentioned above preservation of the original radiometric information is ensured. Storing the raw image data is then supported by the DICOM standard IODs defined in group 28. The bitdepth is defined in tags `(0028,0100) - BitsAllocated` and `(0028,0101) - BitsStored` whereas the image size is specified in `(0028,0010) - Rows` and `(0028,0011)` - Columns. The actual image data is stored in IOD `(7FE0,0010) - PixelData`. Additionally, image compression (e.g. JPEG-LS[1]) can also be specified.

While the above covers the raw image data, in thermal imaging it is obviously the temperature information that is of interest, rather than the digitised values which by themselves are only of limited interpretability. That is, we must map the captured intensities to the calibrated temperature range. Fortunately, DICOM provides a way of (linearly) rescaling the image values. In particular, the IODs `(0028,1052) - Rescale Intercept` and `(0028,1053) - Rescale Slope` provide the means for a linear transformation of the form $T = I * slope + intercept$ where $I$ is the original intensity value and $T$ the corresponding temperature. The slope and intercept can be derived from the temperature range of a thermogram.

Manufacturer and camera information can be stored in tags `(0008,0070) - Manufacturer` and `(0008,1090) - ManufacturersModelName`.

### B. Pseudo-colour display

The information outlined so far is sufficient to store the image data and to map it to the original temperature values. However, while thermal images are in essence grayscale images (with temperature as dimension) they are usually displayed in false colour, using a colour lookup table that maps intensity values to certain colours in order to ease interpretation. Fortunately, this strategy is not unique to infrared imaging but is also common in other medical domains. Consequently, DICOM has built-in support for storing lookup tables and hence for false-colour image support. The related IOD that capture this information are again in group 28, in particular tag `(0028,0004) - PhotometricInterpretation` which is set to `PALETTE COLOR` indicating the existence of a false-colour image. Then IODs `(0028,1101) - RedPaletteColorLookupTableDescriptor`,

[1] In a study [6] based on a large set of medical infrared images JPEG-LS has been identified as a suitable lossless compression algorithm for thermograms.

(0028,1201) - RedPaletteColorLookupTableData, (0028,1102) - GreenPaletteColorLookupTableDescriptor, (0028,1202) - GreenPaletteColorLookupTableData, and (0028,1103) - BluePaletteColorLookupTableDescriptor, (0028,1203) - BluePaletteColorLookupTableData contain the length and colours of the lookup tables for the red, green, and blue colour channels respectively (each grayscale value is mapped to a (red,green,blue)-triplet).

### C. Patient information

One of the advantages of DICOM is that it provides a uniformed approach of not only storing medical images but also all related information. Obviously some of the most important information in that respect concerns data about the patient and information relating to the study and the corresponding physician. We therefore make use of the standard IODs defined for these purposed in DICOM. For example patient information is stored in group 10 which contains tags such as (0010,0010) - PatientsName, (0010,0030) - PatientsBirthDate, and (0010,0040) - PatientsSex. Information related to the study are kept in group 8, some of the more important IODs here are: (0008,0020) - StudyDate, (0008,0090) - ReferringPhysiciansName and (0008,1030) - StudyDescription.

### D. Standard poses and regions of interest

In an attempt to standardise the capture of medical infrared images and in order to build an atlas and database for the temperature distribution of the skin in human subjects a series of standard views have been defined in [5]. In total 27 standard views comprising regions of the human body that are likely to show significant temperature changes in case of physiological effects due to disease have been specified. Also, for each view one or more regions of interest (ROIs) comprising certain anatomical areas or regions useful for analysing the temperature distribution therein have been defined.

In a DICOM file information about the pose can be included in IOD (0018,0015) - BodyPartExamined. However, the definition of ROIs requires more thought. One possibility would be to store them in a format similar to the one suggested in [5] which is also employed in CTHERM [4], where each region is defined as either an ellipse, a rectangle or a polygon and the necessary data defining the size and position of the mask is stored. Following this approach would however require the definition of new IODs to be stored in the private part of the DICOM file. Clearly, we want to minimise the information stored in that part in order to maximise the support through existing software and hardware solutions. We therefore adopt DICOM's ability to save overlay information to define the mask of each ROI. Up to 16 overlays can be stored with each image which is sufficient for all 27 standard poses. ROIs are stored in the following IODs of group 6000 to 601E:

- (60xx,0010) - OverlayRows
- (60xx,0011) - OverlayColumns
- (60xx,0052) - OverlayOrigin
- (60xx,0100) - OverlayBitsAllocated: set to 1
- (60xx,3000) - OverlayData
- (60xx,0022) - OverlayDescription

OverlayData contains the actual ROI mask which is position according to OverlayOrigin. In OverlayDescription the definition of the ROI is contained (e.g. "lateral hip"). Statistical information about the temperature distribution within the ROI can be stored in (60xx,1302) - ROIMean and (60xx,1303) - ROIStandardDeviation.

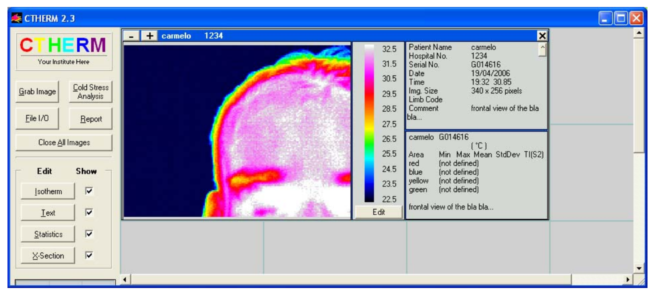


Fig. 1. CTHERM screenshot displaying head thermogram.

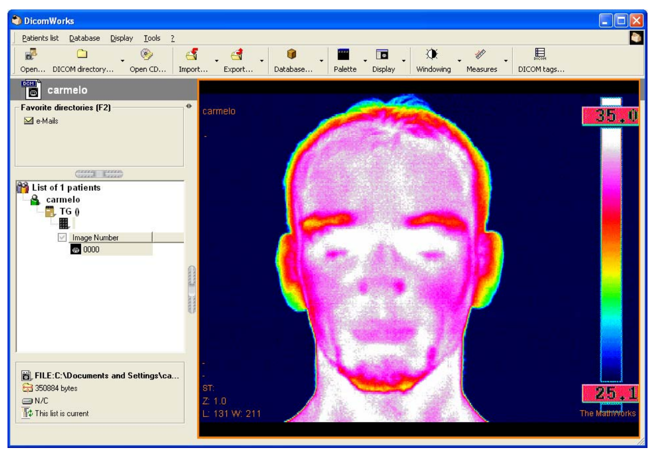


Fig. 2. Screenshot of a common DICOM viewer displaying the same thermogram as in Figure 1.

### E. Private IODs

Although the data covered above certainly include all main aspects of storing thermograms, some additional information might be useful for which no standard tags are defined in DICOM. We therefore store this information in the private part of the file and use group 29 to contain the following suggested IODs:

- (0029,0001) - MinTemperature
- (0029,0002) - MaxTemperature
- (0029,0010) - CameraTemperatureResolution

```
# Dicom-Data-Set
# Used TransferSyntax: LittleEndianExplicit
(0008,0016) UI =SecondaryCaptureImageStorage            #  26, 1 SOPClassUID
(0008,0018) UI [1.3.6.1.4.1.9590.100.1.1.253443422212617182822800429291745398672] #  64, 1 SOPInstanceUID
(0008,0020) DA [20060419]                               #   0, 0 StudyDate
(0008,0023) DA [20060419]                               #   8, 1 ContentDate
(0008,0030) TM [192050.514999]                          #   0, 0 StudyTime
(0008,0060) CS [TG]                                     #   2, 1 Modality
(0008,0064) CS [WSD]                                    #   4, 1 ConversionType
(0008,0090) PN [CJ                                      #   0, 0 ReferringPhysiciansName
(0008,1030) LO [Frontal craneal view]                   #  20, 1 StudyDescription
(0010,0010) PN [carmelo]                                #   8, 1 PatientsName
(0010,0020) LO [CB]                                     #   0, 0 PatientID
(0010,0030) DA (no value available)                     #   0, 0 PatientsBirthDate
(0010,0040) CS (no value available)                     #   0, 0 PatientsSex
(0018,1016) LO [The MathWorks]                          #  14, 1 SecondaryCaptureDeviceManufacturer
(0018,1018) LO [MATLAB]                                 #   6, 1 SecondaryCaptureDeviceManufacturersModelName
(0020,000d) UI [1.3.6.1.4.1.9590.100.1.1.225922154411778892922877367192314012871] #  64, 1 StudyInstanceUID
(0020,000e) UI [1.3.6.1.4.1.9590.100.1.1.377739078911229888325586254403420789484] #  64, 1 SeriesInstanceUID
(0020,0010) SH (no value available)                     #   0, 0 StudyID
(0020,0011) IS (no value available)                     #   0, 0 SeriesNumber
(0020,0013) IS (no value available)                     #   0, 0 InstanceNumber
(0020,0020) CS (no value available)                     #   0, 0 PatientOrientation
(0020,0060) CS (no value available)                     #   0, 0 Laterality
(0020,4000) LT [Long comments about the image posted here...] #  44, 1 ImageComments
(0028,0002) US 1                                        #   2, 1 SamplesPerPixel
(0028,0004) CS [PALETTE COLOR]                          #  14, 1 PhotometricInterpretation
(0028,0010) US 512                                      #   2, 1 Rows
(0028,0011) US 680                                      #   2, 1 Columns
(0028,0100) US 8                                        #   2, 1 BitsAllocated
(0028,0101) US 8                                        #   2, 1 BitsStored
(0028,0102) US 7                                        #   2, 1 HighBit
(0028,0103) US 0                                        #   2, 1 PixelRepresentation
(0028,0106) US 0                                        #   2, 1 SmallestImagePixelValue
(0028,0107) US 255                                      #   2, 1 LargestImagePixelValue
(0028,1052) DS [0.0392]                                 #   6, 1 RescaleIntercept
(0028,1053) DS [25.5000]                                #   8, 1 RescaleSlope
(0028,1054) LO [US]                                     #   2, 1 RescaleType
(0028,1101) US 256\0\8                                  #   6, 3 RedPaletteColorLookupTableDescriptor
(0028,1102) US 256\0\8                                  #   6, 3 GreenPaletteColorLookupTableDescriptor
(0028,1103) US 256\0\8                                  #   6, 3 BluePaletteColorLookupTableDescriptor
(0028,1201) OW 0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000... # 512, 1 RedPaletteColorLookupTableData
(0028,1202) OW 0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000\0000... # 512, 1 GreenPaletteColorLookupTableData
(0028,1203) OW 0df2\0df2\1ce3\1ce3\2bd4\2bd4\3ac5\3ac5\49b6\49b6\58a7\58a7\6798... # 512, 1 BluePaletteColorLookupTableData
(0029,0001) DS [25.5]                                   #   4, 1 PrivateGroupLengthToEnd
(0029,0001) DS [22.5]                                    #   4, 1 MinTemperature
(0029,0002) DS [32.5]                                    #   4, 1 MaxTemperature
(0029,0010) DS [0.05]                                    #   2, 1 CameraTemperatureResolution
(0029,0011) DS [0.1]                                     #   2, 1 CameraTemperatureAccuracy
(0029,0020) DS [22.0]                                    #   4, 1 RoomTemperature
(0029,0021) DS [20]                                      #   6, 1 RoomHumidity
(7fe0,0010) OB 09\09\05\09\05\09\09\09\09\09\09\09\09\09\09\05\09\05\05\09\05\09... # 348160, 1 PixelData
```

Fig. 3. Parts of the dump of the DICOM image of Figure 2.

- `(0029,0011) - CameraTemperatureAccuracy`
- `(0029,0020) - RoomTemperature`
- `(0029,0021) - RoomHumidity`

We note that although we are able to map the intensities to temperature values through a rescaling function we still suggest to store the minimal and maximal temperature explicitly as they are often of practical use. The other fields should be self-explanatory from their respective names. Other, additional information, for example information regarding protocols for patient preparation can also be included in the private part of the DICOM file.

## IV. AN EXAMPLE

In order to evaluate the correctness of our proposal and test its usefulness in practise we have written a conversion program that will transform a CTHERM image to a DICOM file. In Figure 1 we show a screenshot of a head image displayed in CTHERM. The image was converted using our software and then opened in a common DICOM viewer as displayed in Figure 2. As can be seen the DICOM viewer can successfully open and interpret the generated file and display it correctly in false-colour which in turn proves the compatibility of our proposal presented in this paper. A dump of some of the important IODs of the generated DICOM file is given in Figure 3.

## V. CONCLUSIONS

In this paper we have presented a first proposal on how the common DICOM standard can be adopted for storing and communicating medical infrared images. It has been shown that virtually all of the required capabilities are contained in the standard and hence that such an adoption is indeed possible.

We hope that this initiative might stimulate the foundation of a dedicated DICOM workgroup for thermography to establish a full integration of this modality into the standard and to involve manufacturers of thermal cameras into the process.


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