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A digital interface designed for sharing diagnostic medical imaging with patients

— Final Report —

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Abstract

In a world where access to data is becoming faster and easier everyday, how could we prevent the society from the desire to have a better and more systematic **access to medical data**? In particular, in the field of **Medical Imaging**, which propose a range of routinely used methods to produce precise representations of the inner humans body and diagnose serious diseases? And especially, in the **United Kingdom**, where medical imaging data sound like a well kept mysterious treasure? Apparently we can't, and some solutions are popping up on the way to deal with it.

Indeed, some researches have already been led in the United States concerning the creation of a **"patient portal"** [1]. The main idea beeing to provide the patient with a suitable graphical interface that would display their medical images and help them to understand what they see. **Dr Fernando Bello** and **Pr William Cox** took the bet of digging in that particular area to explore the benefits and risks that could come from the conception of such an interface. They ended up to propose the effective realization of this interface, as a final personnal project to the **departement of Computing Science at Imperial College of London** together with the **Chelsea and Westminster Hospital**.

Consequently, the following report offers an overview of the work undertaken during the last three month on the creation of **"A digital interface designed for sharing diagnostic medical imaging with patients"**. From specifications to conception, throught design and testing, the aim of the following document is to present the different stage of the interface realisation, including issues, skills earned, and the final output that will be left as a basis for further development.

Acknowledgements

”It is usual to thank those individuals who have provided particularly useful assistance, technical or otherwise, during your project. Your supervisor will obviously be pleased to be acknowledged as they will have invested quite a lot of time overseeing your progress.”

Person to thank:

- I would like to express my deep gratitude to Professor Dr Fernando Bello

- Will Cox

- Co-workers at Chelsea and westminster hospital

- Developper community over the internet and around me

Contents

1 Introduction

According to a study published in January 2018 from **National Health Service (NHS) England** [2], 41.4 million of **imaging tests** have been reported in England between October 2016 and December 2017. Indeed, **medical Imaging** exams are routinely used all over the world to explore internal body structures and/or diagnose diseases. This generic term gather together various clinical methods, such as, **Magnetic Resonance Imaging** (MRI), **Computerized Tomography** (CT-Scan) or **X-Ray**, which allow to produce a 2D or 3D representation of physical intern structures.

Methods used for those review are common, and since the introduction of the **DICOM standard** in 1985 [3], so is the professional storage and communication system. However, when it comes to sharing diagnoses with patient, each country get to developp its own methods. In the **United Kingdom**, it is less than likely that a patients get, or even ask, access to their medical data. On demand and providing payment, one can get his plain clinical images. But generally, patients have only access to their clinical report, by means of a general practitioner, and the medical images remain a mystery black box that no one get to see.

Simultaneously, with the evolution of technology making access to knowledge easier day after day, access to **medical informations** is also more coveted and especially concerning **imaging data**. However, the issue about sharing those sensitive data, is not only to promote access, but essentially to make those images affordable for the common mortal. Researches have already been made in the United States concerning the creation of a **"patient portal"** [4] - fully designed to facilitate **patient understanding** - exploring the related opportunities, and scaling different levels of benefit.

Taking all those facts into consideration, **Dr Fernando Bello** and **Pr William Cox** have decided to deepen the subject of designing a **patient portal**. First by exploring the **benefits and risks** from sharing medical informations with patient and thereafter by effectively building such an interface. Consequently, after a year of background researches, they offered to work on the creation of **"A digital interface designed for sharing diagnostic medical imaging with patients"**, as a final personnal project to the **departement of Computing Science at Imperial College of London**, together with the **Chelsea and Westminster Hospital**. Aiming to build an interface **suitabely made for imaging patients** in order to let them access and understand their medical results in the most significant and comprehensible way.

The following report contains an overview of the work undertaken during almost three month beginning late May 2018 under the supervision of **Dr Fernando Bello** and **Pr William Cox**. The following parts will developp in a logical order - for better understanding - the several steps reached during the conception of the interface, including issues, skills earned and personnal review.
//To do once the plan in certain I will first set up in detail the context of the project and developp the early specifications

2 Background and Related Work

2.1 Project premises and Goal definition

–¿ Will PhD work
–¿ litterature review
–¿ developp section about benefit
Providing medical data to a patient is always a delicate step in a medical procedure. According to medical imaging, there are 2 manners to share data with patient, either under the control of a clinical expert, or recently via standalone technologies which could left the patient with some doubts.
While sharing this data on a digital interface ¿ benefit tot. discuss Subject of will pHD, define in its report + litterature review, a lot of article
Before beginig to work –¿ read though those paper and understand the challenges of this project and why
Challenges to create an interface that could be sufficiant or provide enough to guide on the right track
PATIENT PORTAL = view medical report online PORTAL CAN BE ”DYNAMIC AND TAILORED to patient information preference” IPAD 2
creating an interface that can be progressively adapted in order to fit patient needs.
Why the project:
Medical Imaging exams are routinely used to explore the human body and detect disease.
In the litterature: experience and perceive patient needs in terms of information sharing –¿ IPAD2 = making a study on the benefit of sharing information with patient, how to share, what to share, how will patients reacts - focusedd on lung cancer patient (Los angeles)
A LOOOOOt of litterature in this field, a lot of background work on the benefit, my work come as the final stage of this question
2 BENEFIT: related and unrelated (education etc)
WILL PHD –¿ explore/ quantify the benefit –¿ MY WORK: SET UP his work in order to test it
Some sample patient portal already done
There are plenty of interface to deal with medical imaging but they are all made for doctors.
With this project we want to make something accessible for the patient and valuable for them –¿ will levels of benefit
With concern to provide patient with some ”right” information and don’t let them look over the internet for wrong answers -¿ examples and talking with doctors

2.2 Early specifications

–¿ Why define wpecification before beginning is important in that kind of project
–¿ Show specification defined with Will: can re use what was in background report
Based on my previous experiences concerning the development tool for a third person, it was really important to me to define clearly the specification and limit of the project before starting to properly developp/ code it. This was on one hand to be sure to produce an interface that will suit my supervisors needs and on the other hand to avoid time waste in the future. Specifications concerning the graphical interface have been divided in five part: the basic requirements, the content, the design, the features and some further precisions.
During the early stage of the project we had several meetings with my two supervisor in order to define those specifications. Basically we agreed on the following one:

1. Basics requirement = project goal

2. The content

3. Features and functionalities The interface should provide:

- One doctor oriented window: so, they can fill in datas (images, report) and add flag to images at their conveniance.
- One patient oriented window: read only data (no modification allowed) and the possibility for patient to chat with doctors.

My main concern - in the context of this project - is to focus on the patient oriented side and see how far I can lead this project. This part can be really time consuming as it might need to be oftently readapted following the needs of my tutors.
Also, William recently sent me detailed general specifications concerning the patient oriented interface content/functions - Appendix 1

4. The design In terms of design the first specifications were really basic, it was agreed that I should look around already existing imaging readers in order to get some ideas and that the creation will be done over time.

5. Further Precision

- No access to any database will be provided for the current project (security issues)
- Access to the interface will be local, patient would be given (upon request) a CD with their images loaded on the interface; this wont change patient access to datas but should make them want to access it
- Interface should include user specification/precisions for patient
- Benefits/specifications will have to be defined before starting implementation

- Interface should be windows portable

–¿ appendix: lately provided doc for design

3 Groundwork

3.1 Understanding the imaging file format: DICOM standard

1.Definition

DICOM file format is a special software integrated standard format dedicated to ease data communication between different facilities in the Medical Imaging Field. This standard has been defined by the American College of Radiology (ACR) and the National Electrical Manifactural Association (NEMA) in 1985. DICOM format defines among a lot of others data dictionnary, data structure, file format and comes with a TCP/IP protocole to facilitate data transfer. Before the creation of this standard, it was difficult for different facilities to exchange imaging and imformations, currently this format is widely use for all medical imaging areas such as CT (Computed Tomography), MRI (Magnetic Reasonance Imaging), X-Rays, Ultrasounds, etc.

DICOM format is a well structured piece of work and DICOM standard website [1] provides a large documentation, however, it remains a challenge to fully understand what this is all about.My objective in the following subsection is to give a basic overview of DICOM standard features. As complete the DICOM standard could be, I also used two well formed websites [2] [3], to build my understanding on the DICOM file format.

2.DICOM Information Model structure

Above all DICOM has been created to facilitate information exchange in the real world of patient healthcare services according to Imaging Field.Information that are contained in DICOM objects are related to **Real World** object that could be Patient, Location, Sudies, etc. According to those objects the DICOM Standard has define a **Model of the Real World** - see Appendix X - to identify relationship and interaction between those objects.

Consequently, all information available in DICOM objects will be related to those instances. Based on the **Model of the Real World**, the DICOM standard has defined the **DICOM Data Model**.This Data Model is made of classes called **SOP Class(es)**; one SOP Class is made of one **DIMSE Service Group** together with an **Information Object Definition (IOD)** - see figure 1 .

Information Object Definition are abstract object which are intented to represent **instances of the Real World Model**. More precicely those objects aim at representing classes of element which have some common attributes. **Information Object Definition** are made of **Information Entities (IE)** that stand for the **Real World Object**. All **DICOM Object** must at least contains the SOP common module and the four main **Information Entities**: Patient, Study, Serie and Image.

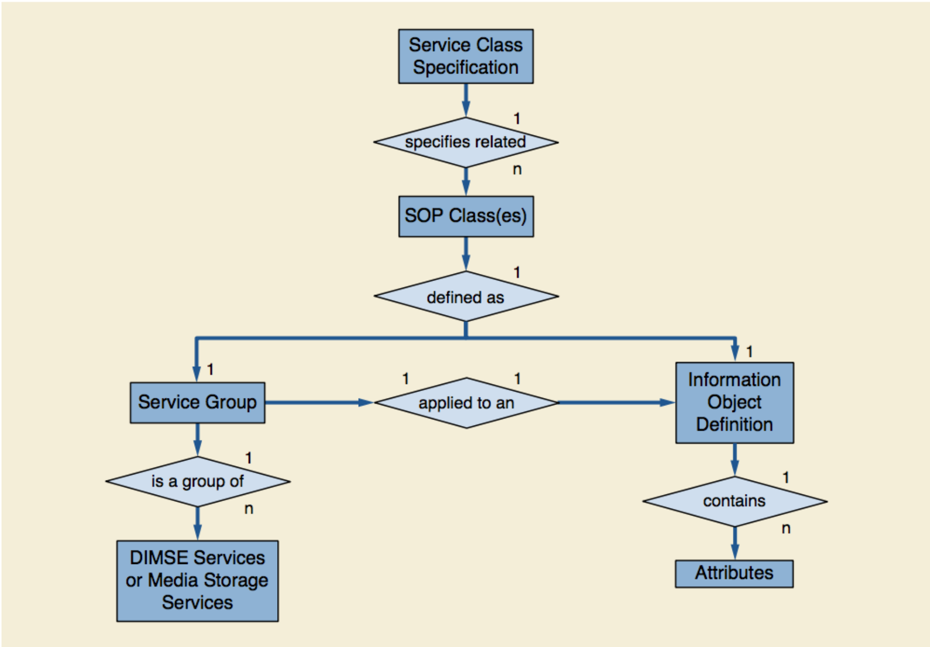

Figure 1: DICOM Informational Model Structure

The **DIMSE Service Group** specifies operations and notifications that can be applied on an IOD, **DIMSE** stands for DICOM Message Service Element, **SOP** are then used for message transfering between **IOD's**. Together those two element form a **Service Object Pair (SOP) class** that contains rules and semantics that rule the use of the services.

When DICOM was created the only instances where images, now other instances that are not images have been introduced but are not of our concern, therefore I will only use the term **DICOM Images** (DICOM Instance that are Image). As said **DICOM Images** are **Information Object Definition**, and must then contain the Image Module besides the four main entieies and the SOP common. This module will contain information about the image itself.
DICOM Images structure is defined on the Figure 2.
To more extend it is clear on the figure that each Information Entities has an attribute called UID, this stands for **Unique Identifier**. DICOM uses those identifiers to uniquely defines a wide variety of items to guaranty global uniqueness, mainly among different countries, sites, equimment.

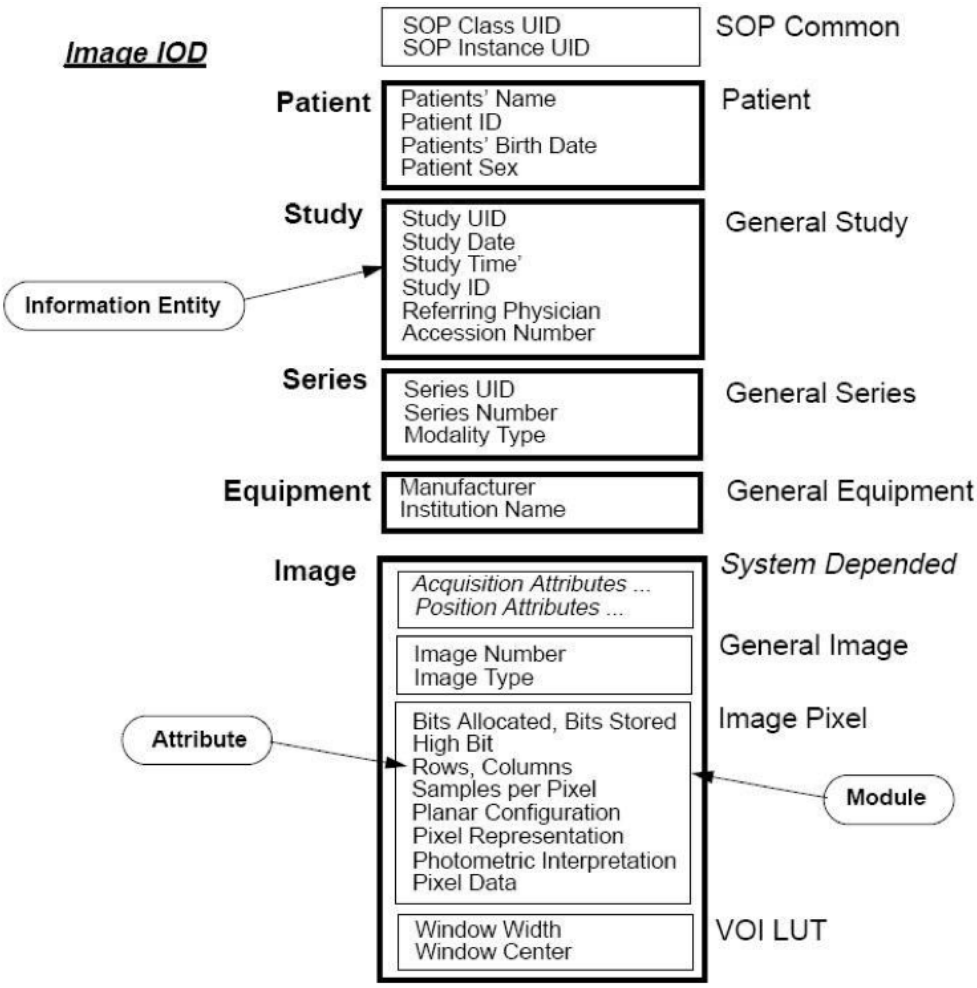

Figure 2: Image IOD structure

3.General File Structure

DICOM file objects contains informations about the **DICOM objects of the Real World**, which we know at this stage are held in **Information Object Definition**. Each DICOM file is composed of two instance: a **Header** followed by a **Data Set**.

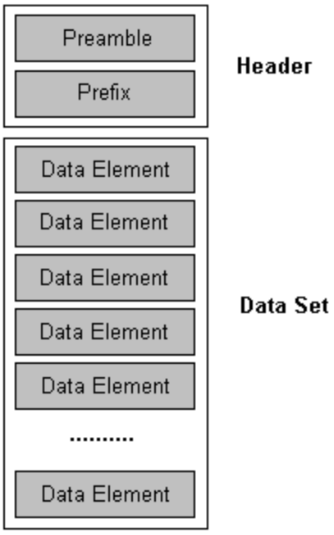

Figure 3: Basic DICOM File Structure

The Header contains 128 bytes preamble (which are all set to zero if it is not used) followed by 4 byte DICOM prefix (DICM). The header is not necessary included in the file but is usefull to make access to data easier, indeed the prefix allows to quickly acknowledge DICOM format. Besides, no structure is required for the preamble.

The Data Set is organised as consecutive **DICOM Data Element** (or Data Attribute) referenced in the DICOM standard. Those Data Element can represent various informations, from the patient name and birth to the pixel image information. More precisely one **DICOM Data Element** is one unit of information corresponding to an encoded **Information Object Definition Attribute** defined above.

DICOM Data Element are Tag Element therefore DICOM can be said to be a tag file format meaning each element is referenced by a unique **Tag Number** which define the element and its properties. The Data Set order Data Elements by increasing Tag Number. Each Data Element is made of the consecutive fields:

- **Tag Number**: ordered pair of 16bits unsigned integer of the form (gggg,eeee) representing the Group Number Followed by yhe Element Number. Eg: (0028,0010): Group Number 0028 correspond to the Image group, Element Number 0010 correspond to the row and especially to the length of the image in pixels

- **Valure Representation**: defines the data type of the element, can be omitted because the Tag Number already implies the data type

- **Value Length**: either 16 or 32 bits, defining the length of the following value
- **Value Field**: even number of bytes containing the value of the element; the value field can contain the Value Multiplicity, which specified the number of value that can be encoded in the value field.

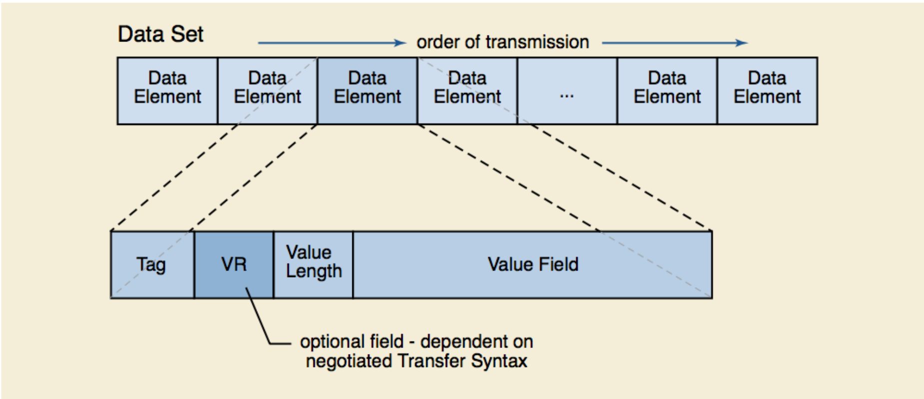

Figure 4: Data Set and Data Element structure

4.The DICOMDIR

In order the get their DICOM imaging data, patient will be given their DICOM folder. Every basic DICOM folder should contain one element called **DICOMDIR**. This **DICOMDIR** is a **DICOM File Object** containing paths to every DICOM Element that is in the folder; paths are organized within patient, study, serie, image. It also contains the genral informations according the the situation (patient information, study ID, date). The folder might contain other non DICOM element (e.g the report) that won't be recorded by the DICOMDIR. This DICOMDIR is the entry point for my interface and allows me to browse through the DICOM provided file and find path to images.

3.2 Choosing implementation methods - C++ and Qt

4 Early stage - Creation of a sample interface: display one CT image

4.1 An external library to deal with DICOM images: DCMTK

1.What is DCMTK

DCMTK is an open-source collection of libraries and applications that has been made to deals with the DICOM format while developping an independant application. This software is widely used by hospitals, companies or private individuals that aim at creating DICOM related desktop software. DCMTK provide several classes and script in order to treat, construct, and convert DICOM files and an internal worklist server in order store, send or receive images.

DCMTK source code repository is available on Github and free for downloading. It is available for both Windows and Unix operating systems. For the purpus However dcmtk toolkit doesn’t came as a prebuilt library

2.DCMTK classes and DICOM Element access

4.2 DCMTK classes and DICOM format

–¿ DICOM undestanding: more complicated fromat than expected: appdnix for DICOM format explanation
–¿ DCMTK installation: see appendix for installation tips + appendix for main classes –¿ Qt tools not so cool

4.3 A journey to sample interface: building and linking the library

5 Interface Design Implementation

5.1 Time schedule overview

–¿ provide calendar of project evolution
-¿ insert gantt

5.2 Main features: development and challenges

6 Results

6.1 Final output

6.2 Third party feedback

7 Evaluation

7.1 Personal evaluation

–¿ explain some choice
–¿ show calcul for different plan output

7.2 Ethic and LSEPI checklist

8 Conclusions and Future work

9 Appendix

9.1 Appendix - DICOM Real World Model Structure

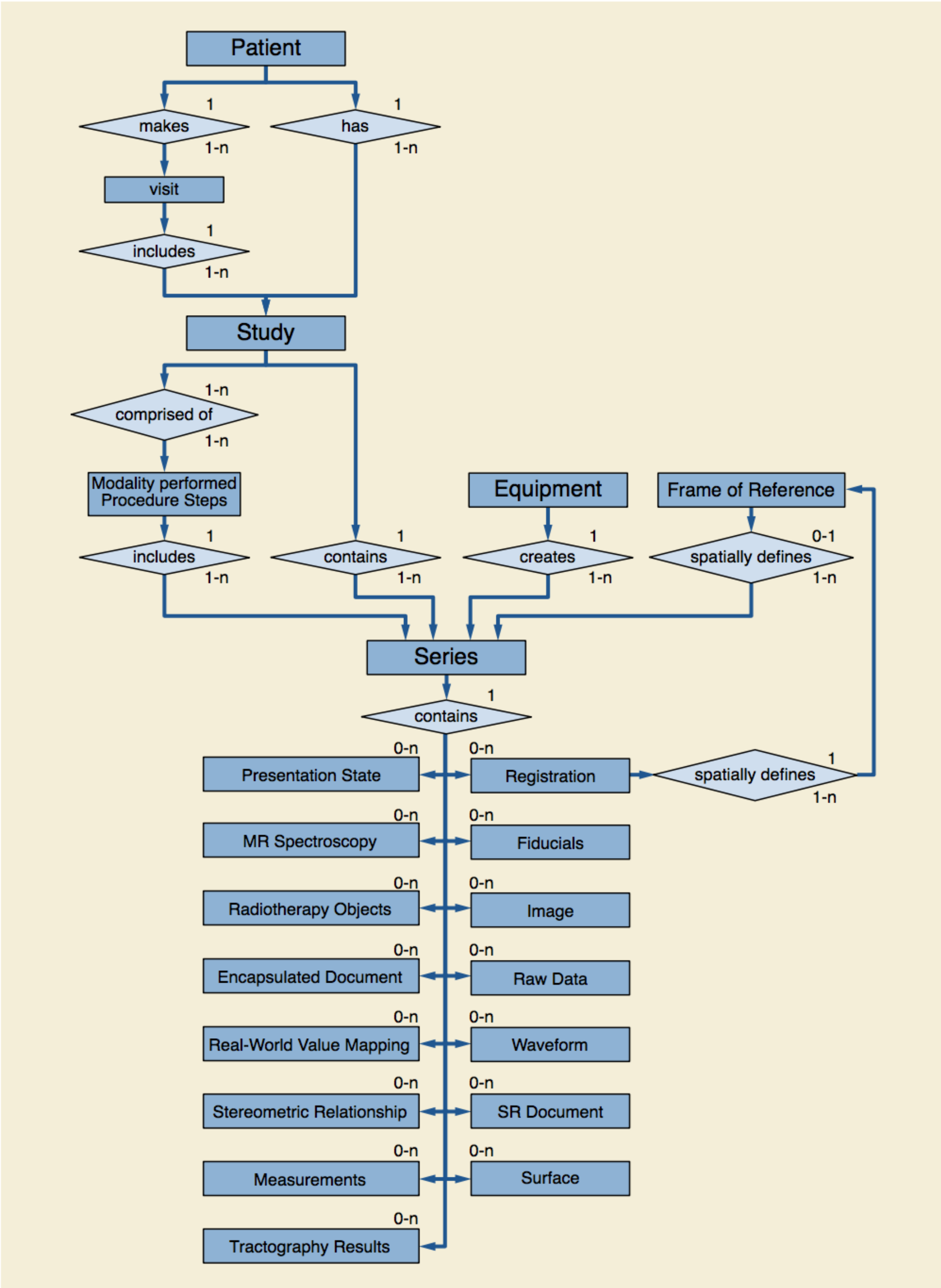

Figure 5: DICOM Real World Model Structure

9.2 Appendix 2 - Imaging Specification

9.3 Appendix 3 - Code Overview