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The development of a DICOM import software and Modality Calculators for Radiology Protocols

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THE DEVELOPMENT OF A DICOM IMPORT SOFTWARE AND MODALITY
CALCULATORS FOR RADIOLOGY PROTOCOLS

by

Jiawen Chen

A thesis submitted in partial fulfillment
of the requirements for the Master of Science
degree in Biomedical Engineering in the
Graduate College of
The University of Iowa

August 2015

Thesis Supervisor: Associate Professor Vincent A. Magnotta

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

_____

This is to certify that the Master's thesis of

Jiawen Chen

has been approved by the Examining Committee for
the thesis requirement for the Master of Science degree
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ABSTRACT

Medical imaging can involve different modalities, such as computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), ultrasound, and etc. Each examination generated by these modalities has a particular protocol, which are imaging parameters determine the signal and contrast for creating a particular image. Properly managing imaging protocols guarantees the quality of scans by providing the radiologist and technicians with appropriate procedures for a given indication. It is also important to ensure patients' safety by reducing repeated scans to acquire the desired image information.

Radiology Protocols (RP) is a company that provides an online imaging protocol database to improve protocol management. It recently developed RP Import, a Digital Imaging and Communications in Medicine (DICOM) import software, to supports the protocol import by automatically collecting elements from the DICOM files and mapping them to the specified protocol database. With RP Import, protocol creation is much faster and eliminates manual definition of the parameters, thus this tool lays the foundation for the further development of imaging protocol management.

Radiology Protocols also developed a series of Modality Calculators to assist radiologists and technicians to build or modify imaging protocols. These calculators cover most of the essential medical parameter calculations associated with different modalities, such as MR acquisition time, CT equivalent and so on. By using them, computing specific parameters while editing protocols becomes more convenient, and

determining the use and amount of certain medical parameters becomes more precise as well.

In summary, RP Import and Modality Calculators are two powerful tools in protocol management, and also play very important roles in regulating procedure and dosage during the medical image practice.

PUBLIC ABSTRACT

Medical imaging can involve different modalities, such as computed tomography (CT),
magnetic resonance imaging (MRI), positron emission tomography (PET), and
ultrasound. Each examination generated by these modalities has a set of unique
instructions, the imaging protocol, which are imaging parameters determine the signal
and contrast for creating a particular medical image. Properly managing imaging
protocols is like systemically documenting an instruction handbook, which guarantees the
quality of scans by providing the radiologist and technicians with appropriate procedures
for a given indication. It also ensures patients' safety by reducing repeated scans to
acquire the desired image information.

Radiology Protocols (RP) is a company that provides an online medical protocol
database to improve protocol management. It recently developed RP Import, an imaging
protocol import software, to automatically collecting elements from the medical imaging
file – Digital Imaging and Communications in Medicine (DICOM) files, and mapping
them to the specified protocol database. With the help of RP Import, protocol creation is
much faster and eliminates manual definition of the parameters, thus this tool lays the
foundation of the further development of imaging protocol management.

Radiology Protocols also developed a series of Modality Calculators to assist
radiologists and technicians to build or modify imaging protocols as they are needed.
These calculators cover most of the essential medical parameter calculations associated
with different modalities. By using them, computing specific parameters while editing

protocols becomes more convenient, and determining the use and amount of certain

medical parameters becomes more precise as well.

In summary, RP Import and Modality Calculators are two meaningful tools in

protocol management, and they also play very important roles in regulating procedure

and dosage during the medical image practice.

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Digital Imaging and Communications in Medicine (DICOM) import software (RP

Import) and Modality Calculators are applications for managing medical imaging

protocols. In this chapter, the motivation for developing these two applications is

introduced.

Section 1.1 explores the need for managing medical imaging protocols by

describing the size of protocol management market, and pointing out the shortcomings of

mismanagement of the imaging protocols.

Section 1.2 analyzes the demand for building an on-line medical imaging database

by listing weaknesses of the current medical imaging database and presents the benefits

of having an on-line medical imaging database.

1.1 The need for managing medical imaging protocols

Medical imaging, images of the human body for medical purposes, can involve

different modalities, such as computed tomography (CT), magnetic resonance imaging

(MRI), positron emission tomography (PET), ultrasound, and others. Each examination

generated by these modalities has a particular protocol, which are imaging parameters

determine the signal and contrast for creating a particular image. These protocols are the

instructions as well as properties of medical imaging scans, they may include

specifications like scanning speed, contrast, rotation rate, etc.

Protocol management refers to storage, maintaining and manually updating

imaging protocols, which could usually be time-consuming. There is a large need for

protocol management across the entire medical imaging industry. The market of protocol management consists of hospitals, health networks, imaging centers, medical groups, private practices and educational institutions. As of 2012, there were 5,723 hospitals in United States (Sebelius et al., 2013) and 23,170 hospitals in China (Braithwaite, 2014). It has been estimated that there are currently 25,000 MRI scanners in use worldwide (Rinck, 2013). Five billion medical imaging studies had been conducted worldwide (Roobottom et al., 2010). The use of MRI, CT, other imaging modalities have been skyrocketing over the past decades, and inefficiencies in this industry are staggering. It is estimated that repeated medical imaging studies contribute to a $24 billion in waste each year (Radiology Protocols, 2015). Each CT and X-ray study increases a patient's exposure to ionizing radiation and thus increases their chances for developing cancer as a result of the repeated scan. As a result, there is an growing concern of properly managing medical imaging protocol, in order to produce a quality scan by providing appropriate procedures to the radiologist and technicians in real time.

1.2 The demand for building an online medical imaging

protocol database

Most medical centers have their own internal databases, i.e. protocol database, to manage medical images associated with various modalities. In most cases, these databases are used to store and retrieve medical images. However, these databases are limited by their inability, to provide instruction to acquire a more appropriate protocol for a new patient. For example, if a physician needs an image with more contrast in a new patient based on the result of a previous patient, he/she needs to retrieve and edit certain parameters on the preceding image to make an update protocol according to responding

rules. In addition, the patient history needs to be taken into consideration. Unfortunately, the internal database does not provide either a guidance to manipulate the parameters of the imaging protocols, or a warning system to prevent parameters error. These disadvantages make it burdensome for the physician to optimize the quality of imaging protocols a patient-by-patient basis.

Another limitation comes with the specificity of the modality. For example, if a physician needs protocols for multiple modalities, the physician will have to search more than two separate databases to find these desired protocols (Baker, 2015). In this case, it would be more efficient for the physician by using a single database with protocols for all the modalities.

To address these problems, most of medical centers generally use a standard protocol database, such as the American College of Radiology (ACR) Appropriateness Criteria (AC) to search protocols associated with multiple modalities. But these standardized databases do not contain custom protocols generated by the medical centers, and they only serve as a repository for protocol. Therefore, a customized database is highly desired, which includes general and customized protocols associated with various modalities, and warning ability if the ordered protocol is out of specification (Baker, 2015).

Building a cloud-based online medical imaging protocol database is a progressive way to maximize the utilization of database for clinical purpose. Data information delay is detrimental to the diagnoses of the patient. A cloud-based online protocol database allows radiologists and technicians to edit and update imaging protocols immediately from any mobile device that are accessible to the cloud. Likewise, physicians can get the

most updated information by retrieving the medical images. Accordingly, having an

online imaging protocol database can reduce the costly repeated scans, raise productivity

of medical imaging examination and most importantly and ensure the safety of patients.

CHAPTER 2

BACKGROUND REVIEW

RP Import software and the Modality Calculators are innovative products developed by Radiology Protocols, in order to support its core product, RP Essential, which is a management system of imaging protocols. In this chapter, the basic knowledge for better understanding the RP Import and the Modality Calculators is presented.

Section 2.1 gives the background information about Radiology Protocols, and introduces its core product – RP Essential. It also highlights the significance of developing RP Import and the Modality Calculators from the prospect of better assisting RP Essential.

Section 2.2 thoroughly lays out the basic concept of DICOM, including its function as well as composition. Establishing a basic understanding about DICOM is critical for comprehending RP Import.

2.1 Background of radiology protocols

Radiology Protocols was founded by Stephen Baker, BS RT(R)(MR) in 2008. "Baker, an MRI technologist with two decades of industry leadership experience, recognized the frustrations and inefficiencies from lack of protocol management within radiology departments" (Radiology Protocols, 2015).

"Radiology Protocols is dedicated to offer the most up-to-date and advanced imaging guidance available to the worldwide radiology community" (Radiology Protocols, 2015). Accordingly, it launched a cloud-based customizable platform named RP Essentials to document, unify and alter imaging protocols, as well as provide

guidance for medical facilities. As stated on Radiology Protocols' website, "RP Essential

revolutionizes the management of imaging protocols by standardizing and organizing

imaging protocols for improved efficiencies, managing and sharing imaging protocols for

all modalities, updating best practices across entire organizations and notifying users of

all updates immediately". Hence, RP Essential is a perfect solution for fulfilling the need

of imaging protocol management.

As the cornerstone of RP Essential, RP Import is a DICOM import software that

allows users to upload and edit DICOM files, i.e. the original documents format of

medical images produced by scanners, in order to build a customized protocol database.

Before RP Import is developed, RP Essential relied on manually retrieving DICOM

elements from the imaging protocols' screenshots taken by the users to fill the protocol

databases, manually mapping was a great way to populate and test the databases, but it

does not scale to an expanding business where hundreds of users may be creating

protocols. Therefore, there is a significant demand to automate protocol creation by

extracting the protocol information from DICOM images. More information about RP

Import will be covered in Chapter III.

As another important application of RP Essential, Modality Calculators serve the

purpose of regulating medical parameters through precise calculations. Modality

Calculators, as its name implies, is a series of medical parameter calculators, which

associated with various modalities, including Ultrasound, CT and X-ray, MRI and

PET/SPECT. With the help of Modality Calculators, radiologists and technicians can

easily produce an appropriate protocol by calculating parameters in advance, or define an

"optimal" protocol based on an initial suggestion. More examples of the Modality Calculators will be presented in Chapter III.

Radiology Protocols is the only company offering the imaging service described above, and thus has great potential to have a significant impact on the medical imaging field.

2.2 The basic concept of DICOM

Before introducing the rationale of RP Import, we need to establish a basic understanding of DICOM. "DICOM standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images, such as CT scans, MRIs, and ultrasound" (Bhagat & Atique, 2012).

In General, there are two main purposes of DICOM. The first purpose of DICOM is diagnosis, DICOM files are created by medical imaging equipment to store medical images. These images can be displayed by using DICOM viewers or specific computer software applications, then diagnosed the findings from these images by doctors. The second purpose is for communication. DICOM protocol is being used to exchange information including DICOM images, patient, procedure data and all medical imaging applications connected to the hospital network. To achieve these two purposes, a DICOM file uses a dynamic header structure to store patient information (name, ID, birth date and sex), important acquisition information (equipment modality, manufacture and model), and context of the imaging study, i.e. the medical treatment description. The DICOM network protocol has the capability of searching, archiving and restoring the imaging studies in the workstation like PACS, as well as controlling and monitoring the treatment procedures (ICOM is Easy, 2011).

Typically, a simplified DICOM data model looks like Figure 1. A single DICOM file (the right part of Figure 1) contains three parts of information: DICOM header, DICOM File Meta Information (data elements) and a single Server-Object Pair (SOP) instance. The introduction and prefix about the DICOM file are stored in the header portion, while the information about the patient's name, the type of scan, acquisition date, etc. are stored in the DICOM File Meta Information portion, as well as the information about the image itself including the image pixel information, i.e. image data is stored in the SOP instance. Such specific format allows DICOM files have to be compressed into a smaller size image or converted to text format. For example, DICOM image data can be compressed using lossy or lossless variants of JPEG format (DICOM introduction and free software, n.d), and DICOM header can be transformed as XML format. RP Import development benefits from this flexibility of the DICOM format.

The DICOM Meta information is the key portion used to construct the imaging protocol database. It is composed from DICOM elements (also referred as parameters in this project), and each element has a Tag, VR (Value Representation) i.e. Data Type, Value Length and Value Field (Figure 1). DICOM tag number (gggg, eeee, where gggg is the Group Number and eeee is the Element Number within that Group) is much like a bar code that uniquely defines the element and its properties (DICOM is Easy, 2011). Value Representation defines the data type of the element. For example, the expression of UI stands for Unique Identifier, and US is the acronym for Unsigned Short. The data type information is crucial in setting the fields' property of the imaging protocol table, and so as the Value Length information. Only fields with correct data types can be filled with

corresponding elements, and appropriate value length can avoid data truncation when

building an imaging protocol table in the database.
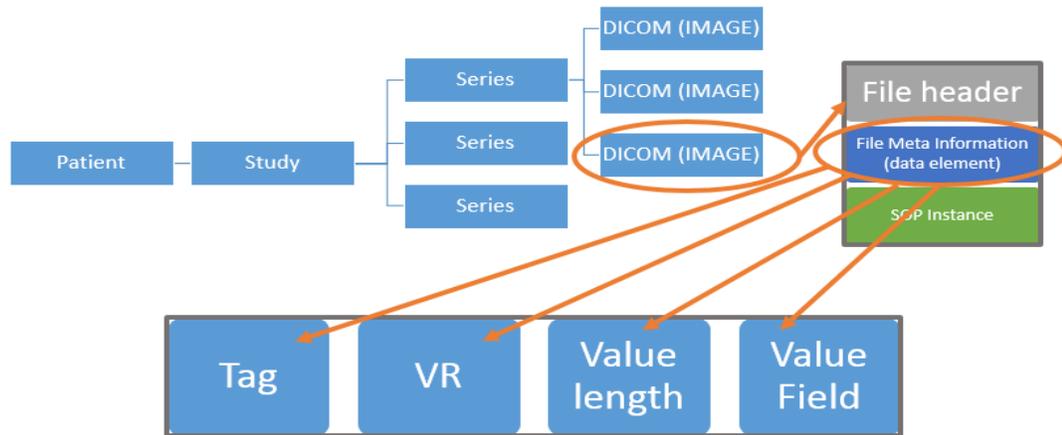
Figure 1. Basic DICOM model and composition

CHAPTER 3

RP IMPORT DEVELOPMENT

RP Import is a software application that can automatically extract specified DICOM elements from DICOM files, and then store them into their corresponding protocol database. It works with DICOM files associated with different modalities, and adapts to multiple DICOM file structure (a single DICOM file or a folder of DICOM files). Further application development will be expanded to multi-frame DICOM files or Mosaic DICOM files. In this chapter, a comprehensive introduction of the development process of RP Import will be specified.

Section 3.1 introduces the motivation for developing RP Import. It first introduces the current mechanism of RP Import's parent product – RP Essential, and analyses the drawbacks of such mechanism. Additionally, it highlights the importance of RP Import development.

Section 3.2 states the product requirements of RP Import. These are the criteria that guide RP Import development, as well as validate the RP Import implementation.

Section 3.3 lays out the design and development process of RP Import. It is divided into four phases according to the development timeline: DICOM convert, DICOM import, DICOM select and the integration process. A set of flowcharts is used to better describe each process.

Section 3.4 mainly presents the flowchart of RP Import mechanism in the actual implementation. It explains how RP Import works in practical use, and points out the shortcomings of the current implementation.

3.1 Motivation

RP Essential is an unprecedented product developed by Radiology Protocols to scientifically manage medical imaging protocols through an online database platform (figure 2). Its mechanism is collecting imaging protocols (not in DICOM format) from the users, followed by manually extracting a list of parameters (DICOM elements) from each imaging protocol, such as Patient's Name, Modality and Institution Name, and then using them to fill an imaging protocol table on the Radiology Protocol website (Figure 4). Imaging protocols tables that belong to the same DICOM study would be labeled and classified as different runs (refers to DICOM series) into the same imaging protocol database (Figure 3).

Although RP Essential worked when a small group of clients were using the product, it does not scale well to a large client base. The need to automate this operation became apparent for the following three reasons: unsatisfying user experience, time-consuming data import process, and waste of human resource. Developing RP Import is the key to solve all these problems.
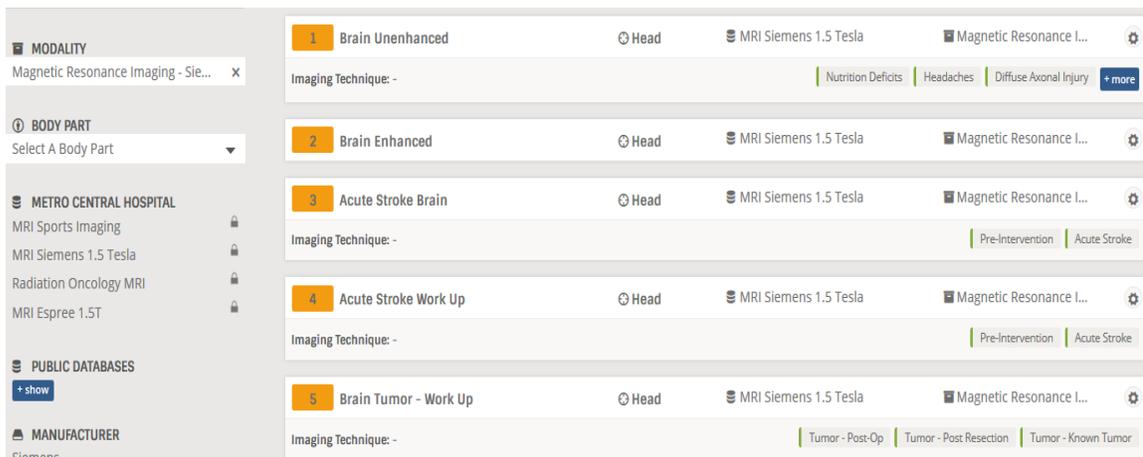
Figure 2. Layout of a protocol database (Radiology Protocols, 2015)
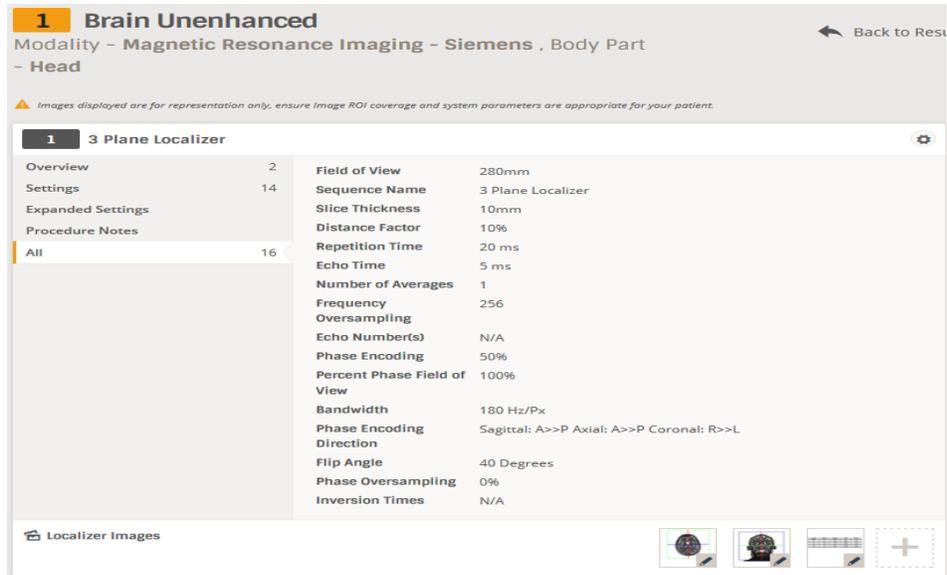
Figure 3. View of a protocol table (Radiology Precools, 2015)

Figure 4. Imaging protocol database with multiple runs (Radiology Precools, 2015)

RP Import is a DICOM import software that collects parameters directly from the DICOM files and maps them into the imaging protocol table automatically. With the help of RP Import, the performance of RP Essential is highly enhanced in three ways.

- First of all, RP Import significantly improves the user experience. Marketing research conducted by Radiology Protocols shows that more facilities are more willing to use RP Essential if they can just simply upload the imaging protocols in their original DICOM format, instead of retrieving the imaging parameters by themselves – in the form of taking screenshots of the medical images and filling out the parameter information sheet (Cowman T, 2014).

- Secondly, RP Import significantly reduces the time of data import process. It used to take an implementation manager more than two days to build a twenty-protocol database with RP Essential. Now it only takes RP Import about one minute to accomplish the same goal.

- Thirdly, RP Import effectively saves human labor for Radiology Protocols. The users themselves can complete the entire DICOM import and mapping process all on their own, so that the workload of the implementation manager will be significantly reduced.

Overall, the motivation for developing RP Import is to satisfy the increasingly rigorous and diverse demands of the protocol management market. There is no doubt that RP Import will support RP Essential in an indispensable way.

3.2 Requirement

As a foundational product for RP Essential, RP Import needs to not only maintain the original functionalities of RP Essential, but also enhances the performance of the database building process. Hence, RP Import should meet the following requirements.

Table 1. Requirements for the RP Import

Original functionalities of RP Essential	New features of RP Import
Presenting protocol table on the website	Automatically extracting DICOM elements
Differentiating different protocol studies	Identifying different DICOM elements
Differentiating different protocol series	Filtering DICOM elements
Labeling protocol series as different runs	Connecting to a MySQL database
Only importing one run per study	Customizing the MySQL database
Having Pre-defined DICOM tags in the protocol table varied from different modalities	Constructing a customized MySQL table formatted with different pre-define DICOM elements
Having a user-friendly interface	Defining the data type and value length of the fields in the MySQL table
Allowing users add, edit or delete DICOM tags from the interface	Uploading DICOM elements into a MySQL table
	Gathering the filtered DICOM elements into a new MySQL table.
	Choosing different MySQL table formats to store DICOM elements based on specified information, like modality or facility information.

3.3 Design and development

There are four phases of the RP Import's design and development process according to the developmental timeline: DICOM convert, DICOM import, DICOM select and the integration process (Figure 5).

Figure 5. Design and development process of RP Import

3.3.1 Phase One

Phase one is the DICOM convert process - design and development of converting the DICOM files into an intermediate file format, which can both represent element values from DICOM files and be imported to MySQL databases.

Extensible Markup Language (XML) is a widely used textual data format, which is not only human-readable but also machine-readable. It can be easily edited by users and simply processed by computers (Extensible Markup Language (XML), 2008). An unlimited number of XML tags can be created and processed as they are needed (Tagarelli, 2011), which satisfies our requirement for handling DICOM elements. In addition, XML is highly adopted by various applications including MySQL database thanks to its straightforward data structure, allowing the XML tags to be effortlessly extracted and uploaded into database. Therefore, XML is an ideal imported file format for MySQL database.
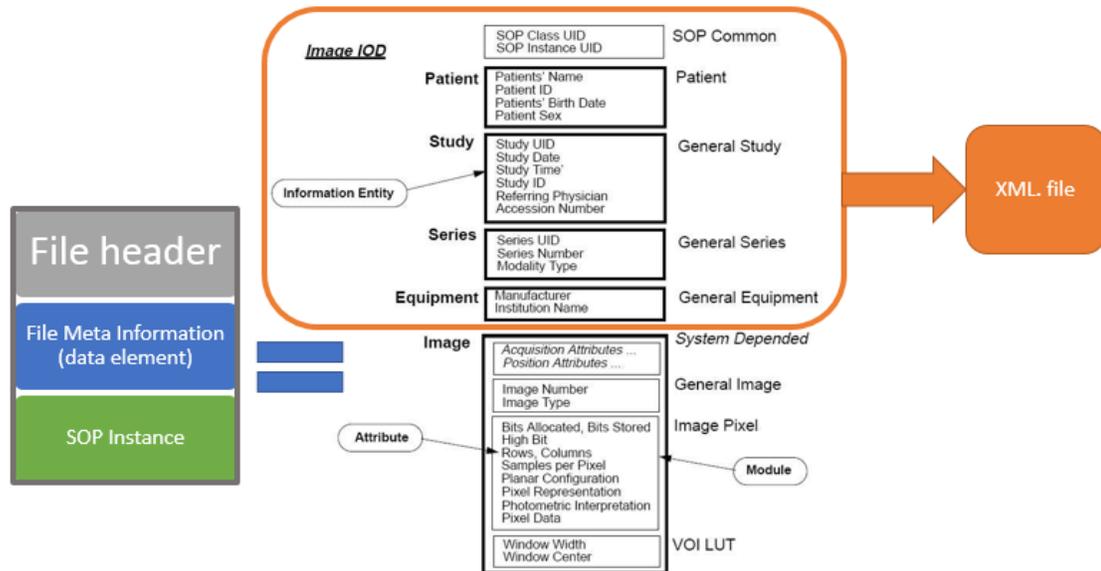

Figure 6. The schema of the DICOM to XML conversion (Amorim, 2014)

Dcm4che2 DICOM Toolkit (dcm4che2) is a high performance, open source implementation of the DICOM standard (Evans, 2012). It contains a number of useful sample applications to operate on a DICOM object, such as dcm2txt, dcm2xml and so on. The way of using dcm4che2 is convenient - downloading the build directory of the toolkit, and executing operations with arguments (file names) inside it.

Dcm2xml is a command-line driven application that converts a DICOM file into an XML representation file (Evans, 2006). The importing file path and exporting file path are specified during the conversion. After the conversion, the values of elements from the DICOM file are stored as the XML tags, while the image data is excluded from the generated XML files (Figure 6). Such arrangement efficiently reduces the size of the XML files, and fulfills the requirements for the imaging protocols import at the same time. With the help of dcm2xml, converting DICOM files into XML format is applicable.

As a result, the XML format is chosen to be the intermediate file format between the DICOM files and the MySQL database, and dcm2xml is used to accomplish the conversion between DICOM files and XML files (Figure 7).
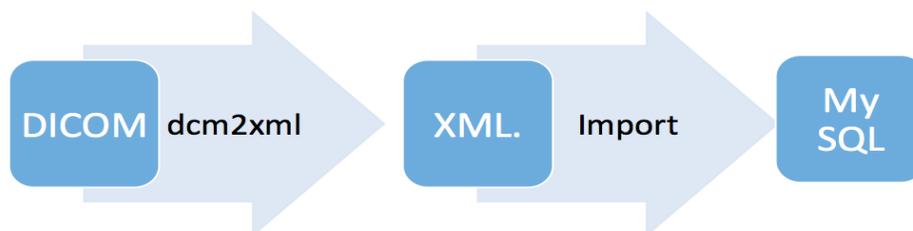

Figure 7. XML as the intermediate file format

<u>3.3.2 Phase Two</u>

Phase two is the DICOM import process – design, develop, and build an

appropriate imaging protocol table MySQL database by importing the XML files

containing the imaging parameters.

MySQL is the world's most popular open source database, which is a relational

database management system or RDBMS as they call it (MySQL, 2015). Using MySQL

database to host the imaging protocol database has four major advantages.

- First of all, simplicity and efficiency. MySQL is a small and fast RDBMS

  database, facing people who have experience on database development. It

  is presented in tabular form, i.e. as a collection of tables and each of that

  consisting of a set of columns and rows (Roebuck, 2012), which makes

  MySQL easier to understand and use compared to legacy hierarchical

  databases and network databases. Besides, the application logic of

  MySQL is also simple enough for developers to build and maintain the

  imaging protocols. Furthermore, MySQL Workbench, a unified visual tool

  of MySQL, enables developers to visually design, model, generate, and

  manage databases, so as to considerably improve the development speed.

- Secondly, cost effective. MySQL database is an open source system,

  which makes it possible to create a free MySQL database for imaging

  protocols.

- Thirdly, cross platform operability. Radiology Protocols requires the

  imaging protocol database to be compatible with all the major platforms,

and MySQL has proved its capability of installing in different platforms with consistently outstanding performance.

- Fourthly, security. Maintaining the confidentiality of the medical information on the imaging protocols is vital to every client of RP Essential, so that only selected users authorized by the facility administrators can entry specified imaging protocol database. MySQL encrypts all the passwords stored during setup process, thus restricting unauthorized access to the imaging protocol database.

The imaging protocol table setting is written in Structured Query Language (SQL) and saved as a procedure in the selected MySQL database. It has three main purposes: creating or connecting a database, creating a table and defining the fields of the table. The first two purposes can be completed easily with user-assigned names and default settings. However, defining the fields of the table is comparatively more challenging.

- Firstly, the basic layout of the protocol table needs to be decided. The default setting of the XML upload is row-based with DICOM tag "elements" as the identifier, which means each row of the table has two fields alone – the name and the value of the DICOM elements. The drawbacks of using such default setting as the actual protocol table are noticeable. For example, this row-based format is not a common fashion to represent data in a table. Besides, the elements that belong to the same protocol cannot be queried or represented by only one identifier. Consequently, the protocol table should be in a column-based format and a unique id should be assigned to each protocol.

- Secondly, the names of the fields on the table need to be defined. Although it is up to the users to decide which DICOM elements are needed for their own protocol table, a list of "fundamental DICOM elements" should be pre-defined as fields in the protocol table, so that the users can edit their protocols based on these pre-defined tags. For example, the "fundamental DICOM elements" for building an MRI protocol are listed in Table 2.

Table 2. "Fundamental DICOM elements" for the MRI protocol table

Protocol ID	Study Instance ID	Series Instance ID
Protocol Name	Manufacturer	Modality
Field of View	Magnetic Field Strength	Petition Time
Echo Time	Spacing Between Slices	Pixel Bandwidth
Flip Angle	Echo Numbers	Inversion Time
Acquisition Time and Slice Location	Number of Phase Encoding Steps	In Plane Phase Encoding Direction
Number of Averages	Imaging Frequency	Percent Phase Field of View
MR Acquisition Type	Slice Thickness	Repetition Time

These DICOM elements are categorized in the Overview, Settings, and Expanded Settings on the MR protocol table webpage of Radiology Protocols (Figure 8). Figure 9 shows the list of "fundamental DICOM elements" for building a CT protocol.

1 3 Plane Localizer ⚙

Overview	2
Settings	14
Expanded Settings	
Procedure Notes	
All	16

Field of View	280mm
Sequence Name	3 Plane Localizer
Slice Thickness	10mm
Distance Factor	10%
Repetition Time	20 ms
Echo Time	5 ms
Number of Averages	1
Frequency Oversampling	256
Echo Number(s)	N/A
Phase Encoding	50%
Percent Phase Field of View	100%
Bandwidth	180 Hz/Px
Phase Encoding Direction	Sagittal: A>>P Axial: A>>P Coronal: R>>L
Flip Angle	40 Degrees
Phase Oversampling	0%
Inversion Times	N/A

Figure 8. "Fundamental MR DICOM elements" (Radiology Precools, 2015)

3 Helical (Volume) ⚙

Overview	5
Settings	2
Expanded Settings	4
Procedure Notes	2
All	13

Region Of Interest	Below base of skull to vertex
Range	140
Collimation Size	0.5x32
Number of Scans	1
Sequence Name	Helical (Volume)
KVP	120
Exposure in mAs	SURE 270
Rotation Time	0.5
Pitch	Detail
CFOV	S
CE	OFF
Acquisition Notes	Total Scan Time(s) 8.0
Direction	OUT

Figure 9. "Fundamental CT DICOM elements" (Radiology Precools, 2015)

- Thirdly, the properties of each field in the table need to be defined. Such properties include data type, value length, allow null option, key, default value and extra setting, which should be defined according to the properties of the corresponding DICOM elements. For instance, one of the MR DICOM elements – Acquisition Date has data type "VR" as "DA",

i.e. date, and the length of value "len" as 8. Thus, the properties of the

Acquisition Date field is "Type – Date, Length – 8, Allow null – No, Key

– N\A, Default – Null, Extra – None." In the practical use, the length of

value is usually defined to be a bit longer to avoid data truncated during

the XML import. Some DICOM elements like Inversion Time, are set to

"allow null" since they do not necessarily have value in every MRI study.

As mentioned above, using the default setting of the XML upload is not favorable

for presenting the DICOM elements, but building the actual protocol table. During the

DICOM elements importation, the "fundamental DICOM elements" should be filtered

from all of the DICOM elements based on the modality information. Since MySQL

cannot identify specific DICOM elements directly from the XML files, yet the default

XML upload can rapidly import all of the DICOM elements from a single XML file into

the temporary MySQL table. Therefore, the official protocol table can query any

particular DICOM element form such temporary table.

3.3.3 Phase Three

Phase three is the DICOM select process – design and development of identifying

the studies and series of the protocols, selectively importing the DICOM files and

assigning different IDs to label them. The modality information is recognized prior to this

process. Notice that only the MR DICOM files have been tested in phase three at this

point.

DICOM study is the set of separate medical examinations (series) for one patient

(Amorim, 2014). For example, a patient takes several medical examinations from MR

and CT in the same study. All the images resulted within these examinations will be

assigned with the same Study UID to indicate that they are from the same study for the same patient. Such a study often contains images from only one modality.

DICOM series is the set of images taken by one modality during a certain examination (Amorim, 2014). In the above example, all the images resulted from MR will share the same Series UID, while other images resulted from CT will share another Series UID, and all of these images share the same Study UID as pointed above (Figure 10). Generally, all images from the same series can only be produced by the same modality.
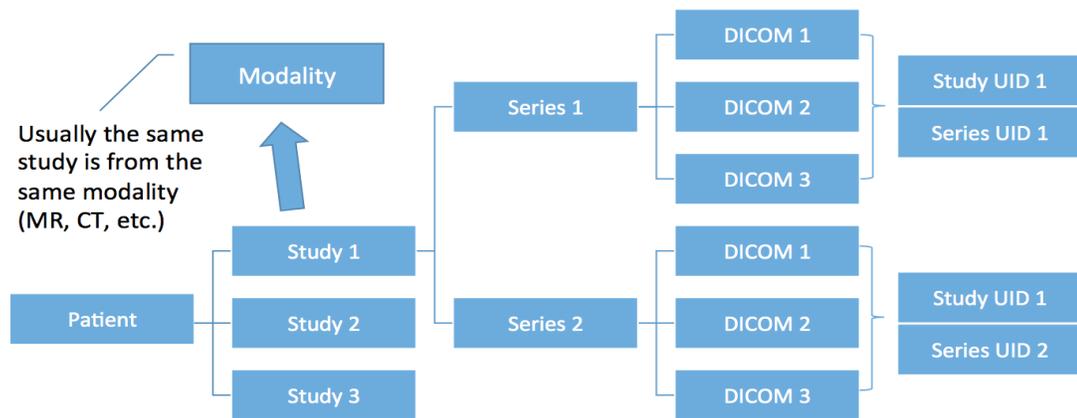

Figure 10. The relationship among study, series, DICOM, Study UID and Series UID

In a real world examination, the DICOM files are stored in the format like Figure 10. Since most of the fundamental DICOM elements (mentioned at section 3.3.2) from the same series remain the same values, only one DICOM file is needed to be imported from each series (such DICOM file is referred as a run in this project) so that duplicated information would not occur. As a result, a seven-step recursive algorithm named DICOM Select is written in order to choose such DICOM file from each series.

DICOM Select is a depth-first search algorithm written in JAVA and its rationale is presented in Figure 11.
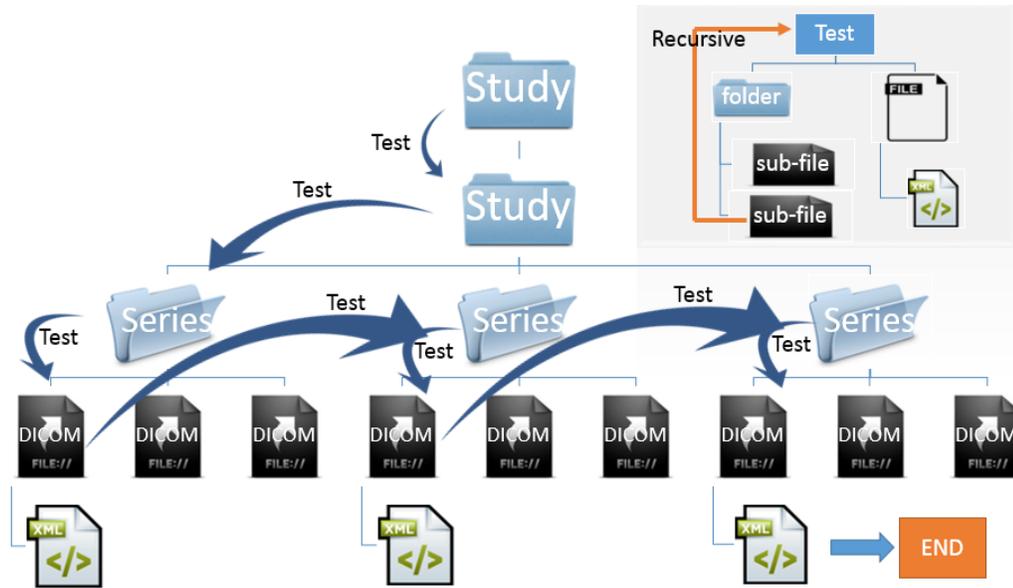
Figure 11. Rational of DICOM Select

- Step one, when a DICOM folder is imported, lists all of the sub-files within such folder.

- Step two, tests the first sub-file and see whether it is a directory or a file. Puts the other sub-files in line for testing later.

- Step three, if the sub-file is a directory, it means the sub-file is either a study folder or a series folder. Therefore, continue listing the sub-files within this directory and repeat step two.

- Step four, if the sub-file is a file instead of a directory, which means such sub-file is a DICOM file and it is the first DICOM file from its parent folder – the series folder.

- Step five, converts this DICOM file into an XML file by dcm2xml and stored it in a new folder.

- Step six, stops testing the rest of the sub-files inside this series folder, and moves on testing the next sub-files in line, which is the folder that shares the same parent folder with this series folder.

- Step seven, terminates DICOM Select when no more sub-file that is left to be tested.

Next, one of the XML files, i.e. a protocol, converted from the selected DICOM files by dcm2xml, is imported into a temporary table named Upload Table. The Modality element from the Upload Table is extracted to determine what modality table and database this protocol should be imported into.

As discussed in section 3.3.2, a unique identifier should be assigned to the protocols for the purpose of searching or differentiating. In this case, such identifier is composed with a Protocol ID and a Run ID.
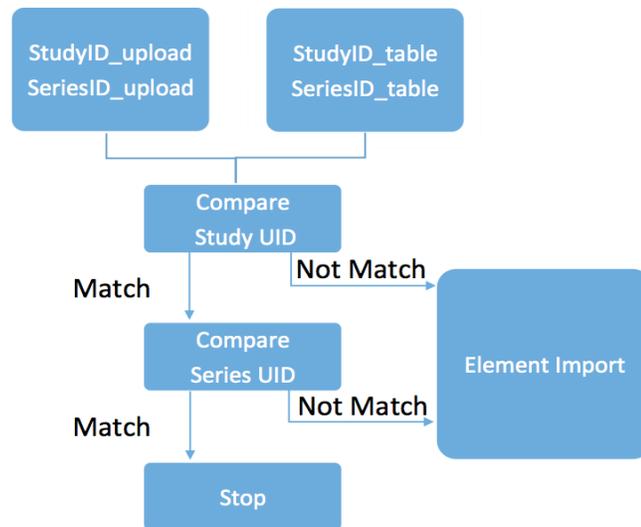

Figure 12. Rational of Runs Compare

A MySQL procedure named Runs Compare is written to assign Protocol ID and Run ID to this protocol by identifying the Study UID and Series UID from the Upload Table. There are nine steps of the Runs Compare, and its rationale is presented in Figure 12.

- Step one, extracts the Study UID as well as the Series UID from the Upload Table.

- Step two, extracts the first existed Study UID and Series UID that are stored in the protocol.

- Step three, compares the Study UIDs. If the Study UID does not match with the first Study UID in the protocol table, goes back to step two and choose the next Study UID in the protocol table then repeats step three.

- Step four, if the Study UID does not match with any of the Study UID in the protocol table, executes the Element Import – a MySQL procedure written in advance to select and import the fundamental DICOM elements into the protocol table. Assigns a new Protocol ID and a Run ID to such protocol, then jumps to step nine.

- Step five, if the Study UID matches with one of the Study UID in the protocol table, assigns the Protocol ID from the matching protocol to such protocol.

- Step six, only compares the Series UID with the group of existing protocols that share the same matching Study UID as such protocol. If the Series UID does not match with the first Series UID, chooses the next Series UID from the group then repeats step six.

- Step seven, if the Series UID does not match with any of the Series UID in the group, executes Element Import, and assigns a new Run ID to such protocol.

- Step eight, if the Series UID matches with one of the Series UID, goes the step nine.

- Step nine, terminates Runs Compare.

The idea of Runs Compare is like checking whether a name – a protocol – is a new name and should be added to a family tree – the protocol table. Imagine there is a family tree with different families – different protocols studies. The same family shares the same last name – Study UID and each family member has different first name – Series UID. Assuming each family member only has one unique name. To check if a name is new to this family tree or not, first by checking its last name with the every family member in such family tree. If such last name does not match with any last names in the family tree, which means this name is definitely a new name and should be added to the family tree – Element Import. If such last name matches with one of the last names, which means these two names come from the same family – study. So far, it is still unclear that this name is a new name, unless its first name is different from other first names of their family. Therefore, its first name is checked with each member from the same family – series with the same Study UID. If there is no matching, that means such name is a new name and should be added to the family tree – Element Import. On the contrary, if there is a match, which means such name is already existed in the family tree and should not be added. Each newly added name is assigned with a unique number – Protocol ID to represent itself.

In conclusion, DICOM Select algorithm can effectively reduce the workload of converting the DICOM files, thereby shorten the processing time of the RP Import. Runs Compare procedure is a crucial step for assigning Protocol ID and Run ID – the most important identifiers in searching protocols.

3.3.4 Integration

Phase four is the integration process of the previous design and development phases. Figure 13 is the flow chart that systematically elaborates the mechanism of RP Import.
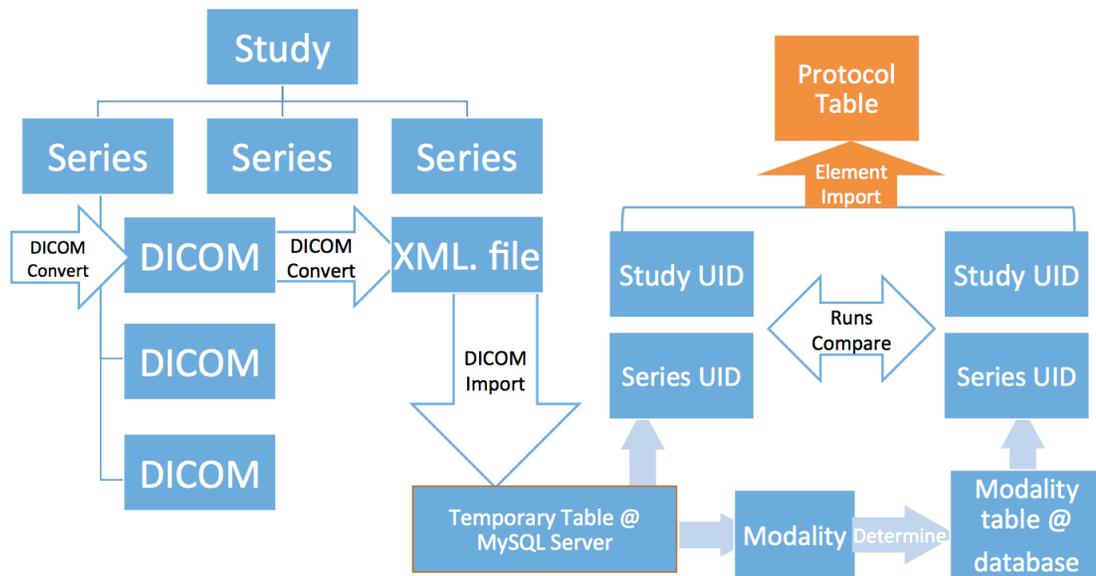

Figure 13. The mechanism of RP Import

RP Import is a JAVA program, embedded with the MySQL procedures written in SQL. It has a simple drag and drop GUI (Figure 14) to visualize the import process, which will be discarded in the implementation process. By pressing the button of "OK"

after dragging and dropping a DICOM folder into the import GUI, the RP Import

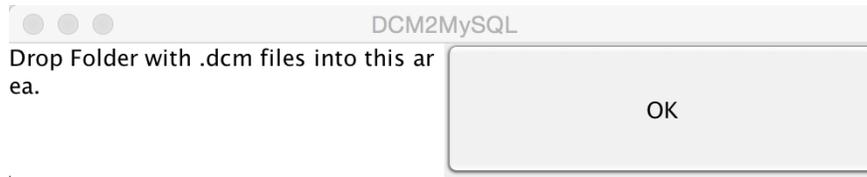program will be executed.

Figure 14. RP Import GUI

- Firstly, selecting only one protocol from each series by the DICOM Select
  algorithm. The name and the file path of such protocol will be displayed to
  indicate which DICOM file has been chosen by the DICOM Select.

- Secondly, converting such protocol into XML file by dcm2xml using file
  path captured in the previous step. The XML file should be named
  properly during setting the file path that directs to the new folder.

- Thirdly, connecting to the MySQL server and ready to import such
  protocol.

- Fourthly, uploading the XML file into the temporary table, and
  determining the type of database and protocol table to host the protocol
  according to the modality information. In the actual application, the type
  of database and protocol table can also be determined by the facility
  information, patient's name or customized setting, etc. Moreover, it is very
  often that an imaging protocol is catalogued in multiple protocol tables or
  database. For example, an MRI brain protocol can be in the general MRI
  database and the general brain database as well.

- Fifthly, creating or connecting the protocol database, building the protocol table if it has not been set up already.

- Sixthly, executing Runs Compare procedure and start importing the protocol. The Protocol ID and Run ID will be assigned to such protocol depends on the result from Runs Compare procedure.

3.4 Implementation

The process of the RP Import implementation pipeline is shown in Figure 15.

- Users apply RP submit, a submission software likes Dropbox, to upload DICOM files to the Radiology Protocol server (RP Server).

- Submission manager manually pushing the DICOM folder into a Linux box where RP Import is hosted. (The reason for manually operating this process is because the RP Server cannot auto detect the DICOM folder. Related software will be developed in the future in order to address this issue.)

- RP Import converts the chosen DICOM files to XML file, and uploads specific DICOM elements into the MySQL database hosted in the Amazon MySQL Server. Such protocol database will then be mapped into another MySQL database for the Quality Assessment, such MySQL database is linked with the active admin interface on the Radiology Protocols website.

- After approving by the protocol manager, the protocol database will be manually imported to the front-end interface on the Radiology Protocols website.

The main goal of RP Import is to automate the protocol creation process. Further refinement and improvements to the post-processing phase of RP Import will be developed in the future (more details on Chapter V).
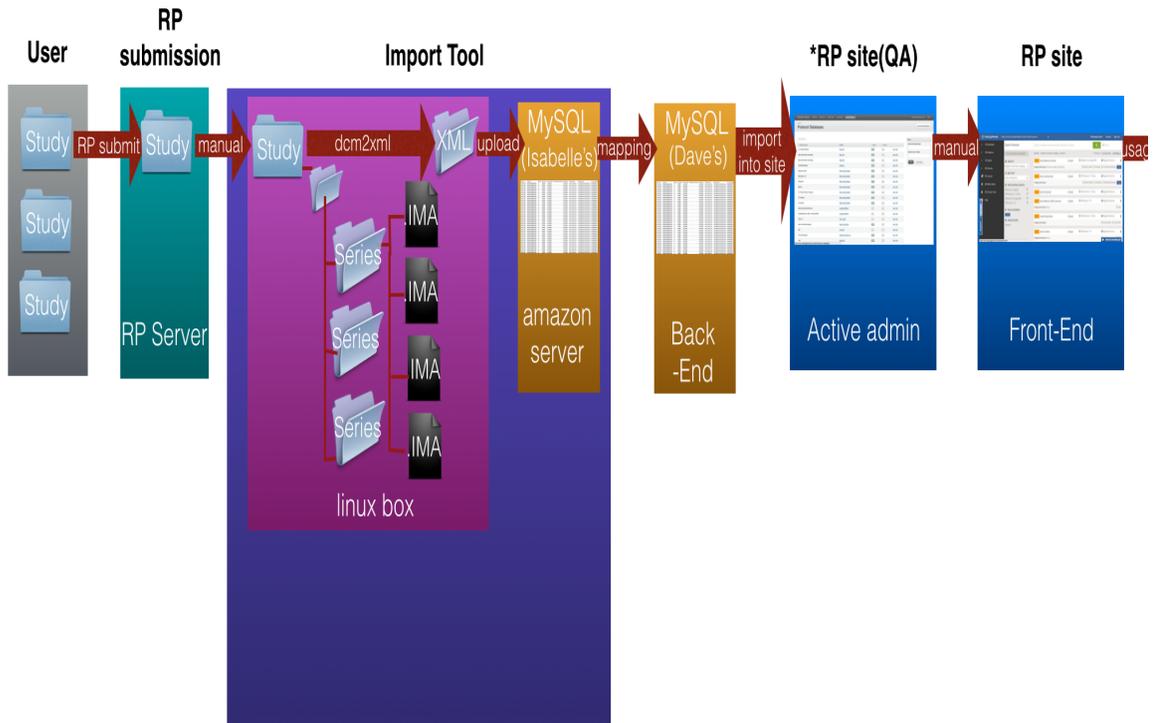

Figure 15. RP Import integration pipeline.

Taking images via network transfer to create a new RP protocol

CHAPTER 4

MODALITY CALCULATORS DEVELOPMENT

Modality Calculators is a series of calculation GUIs that are used to compute a number of important medical parameters associated with various modalities including Ultrasound, CT and X-ray, MRI and PET/SPECT. These standalone GUIs will be integrated into the Radiology Protocols website in the future development, which allows radiologists and technicians to produce appropriate protocols more accurately.

Section 3.1 introduces the motivation of developing Modality Calculators. It first suggests that accurately calculating the medical parameters is the most effective method to improve the quality of imaging practices. It then presents the drawbacks of the current medical calculators, and emphasizes the advantages of using Modality Calculators.

Section 3.2 states the product requirement of Modality Calculators. These are the criteria that guide Modality Calculators' development.

Section 3.3 systematically presents the design of Modality Calculators. Each part includes an overview about the related medical parameter, equations or tables of the related calculations, a screenshot of the calculator GUI and a video of the operation process.

4.1 Motivation

Using Modality Calculators during building or modifying protocols, can significantly improves the precision in determining the dosage of certain medical parameters. It is very important to properly manage the use and amount of each medical

parameter, because any inaccurate dosage or procedure can endanger the welfare of patients. For instance, one of the lethally side effects of radiography is overexposure. Radiation overexposure can lead to a series of complications, such as cancer, malignant tumors and so on. The risk of radiation related diseases is growing because patients are getting imaging examinations like CT too often. Thus, it is critical to control the amount of kVp and mAs when creating the CT protocols. Generally speaking, one of the effective ways to improve the quality of medical image practice is to make sure that medical parameters are specified correctly.

There are various medical calculators being used on the Internet, but none of them are associated with an established imaging protocol database. Modality Calculators is another product of RP Essential. With the help from both of RP Import and Modality Calculators, RP Essential can maximize its functionality as a proper protocol management system. In order to reduce the medical malpractice by monitoring medical parameters, Modality Calculators covers most of the medical image parameter calculations. It preloads the medical parameters from protocol database to the calculator GUIs, and exports the results from the calculators to the protocol interface. In this manner, the calculators can speed up the computation process, as well as enhance the efficiency of building imaging protocols. At this time, the calculation GUIs can only be manually filled with corresponding medical parameters, and further development relies on the development process of RP Import.

4.2 Requirement

For an optimal result, Modality Calculators should meet the following requirements.

Having user-friendly interfaces.

Covering the calculations of most of essential medical parameters associated with different modalities, including MRI, CT, X-ray, PET and SPECT.

Such medical parameters are assigned by Radiology Protocols based on the marketing demand.

4.3 Design

The design of Modality Calculators will be presented in the basic layout of overview, equation or chart, screenshot and video link. The overview section introduces the purpose or function of the calculator. The equation or chart section provides algorithms of the calculation. The screenshot section shows the calculation GUI, and the video link directs to the web address of the operation video demonstration.

4.3.1 Body Surface Area Calculator

1.   Overview

Calculating the Body Surface Area for ionizing radiation doses with descriptive statistics.

2.   Equation

   1) Mosteller formula (Mosteller, 1987) – Recommended and used

BSA (m²) = ([Height(cm) x Weight(kg)]/ 3600)½

      e.g. BSA = SQRT((cm*kg)/3600)

Or in inches and pounds:

BSA (m²) = ([Height(in) x Weight(lbs)]/ 3131)½

e.g. BSA = SQRT((in*lbs)/3131)

2) DuBois and DuBois formula (DuBois & DuBois, 1916)

BSA (m²) = 0.20247 x Height(m)0.725 x Weight(kg)0.425

A variation of DuBois and DuBois15 that gives virtually identical results is:

BSA (m²) = 0.007184 x Height(cm)0.725 x Weight(kg)0.425

3) Haycock formula (Haycock, Schwartz & Wisotsky, 1978)

BSA (m²) = 0.024265 x Height(cm)0.3964 x Weight(kg)0.5378

4) Boyd formula (Boyd, 1935)

BSA (m2) = 0.0003207 x Height(cm)0.3 x Weight(grams)(0.7285 - (0.0188 x LOG(grams))

5) Gehan and George formula (Gehan & George, 1970)

BSA (m²) = 0.0235 x Height(cm)0.42246 x Weight(kg)0.51456

3.   Screenshot
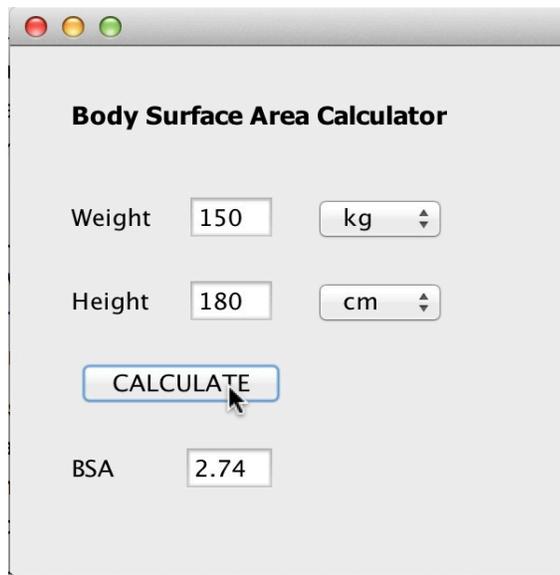
Figure 16. Body Surface Area Calculator

4.   Video link

http://screencast.com/t/U7JdCLlbhTv

<p align="center">4.3.2 MR Acquisition Time Calculator</p>

1.   Overview

Calculating the period of time that is required to collect the image data, which is the product of the repetition time, phase encoding steps, and number of averages.

2.   Equation

2D: Acquisition Time = T_R x Phase Matrix x NEX

3D: Acquisition Time = T_R * Phase Matrix * NEX * # of Slices

- T_R – The repetition time in milliseconds.

- Phase Matrix – The system collects data from the slice once for each phase encoding step.

- NEX - Number of Excitations, the number of times each set of phase encoding steps is repeated.
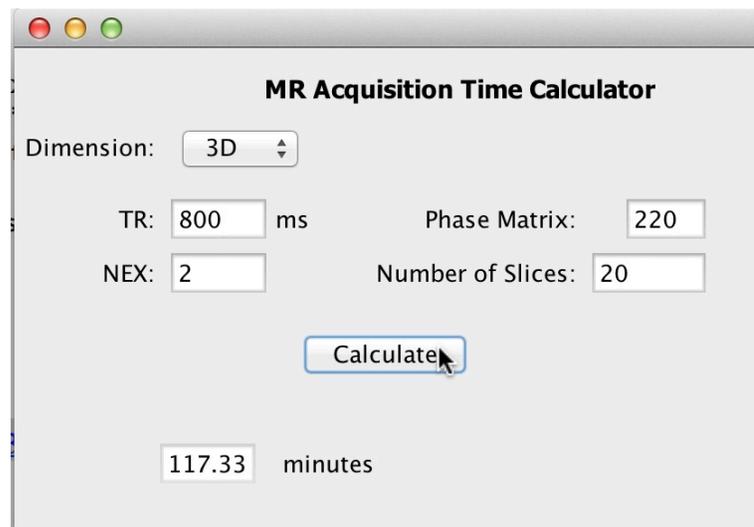
3.   Screenshot

Figure 17. MR Acquisition Calculator

4. Video link

http://screencast.com/t/eIA3BQxiUw2

4.3.3 MR Voxel Size Calculator

1. Overview

    Calculating the length of a voxel grid along the X, Y and Z direction.

2. Equation

    Voxel size = $(FOV)_x/N_x$

    $(FOV)_y/N_y$

    $(FOV)_z/N_z$

- FOV is field-of-View in a particular direction
- N is the acquisition matrix size in a particular direction

3. Screenshot

Figure 18. MR Voxel Size Calculator

4. Video link

http://screencast.com/t/ymCXhfL4bw

<center>4.3.4 MR Pixel Size Calculator</center>

1.   Overview

        Calculating the length of a pixel grid along the X and Y direction.

2.   Equation

        Voxel size = $(FOV)_x/N_x$

                        $(FOV)_y/N_y$

- FOV is field-of-View in a particular direction

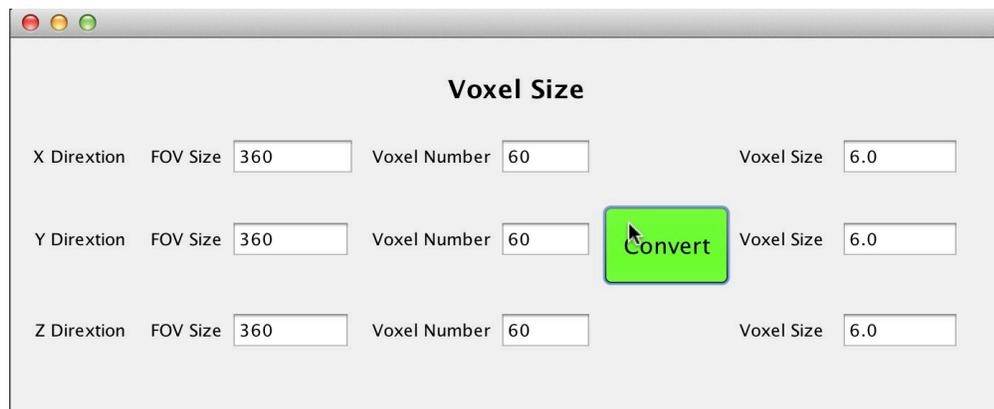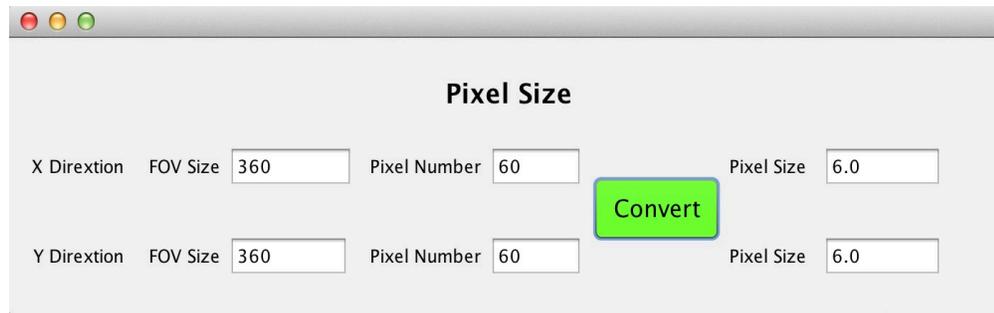- N is the acquisition matrix size in a particular direction

3.   Screenshot

<center>Figure 19. MR Pixel Size Calculator</center>

4.   Video link

        http://screencast.com/t/l9xtpW6cS5

<center>4.3.5 MR Ernst Angle Calculator</center>

1.   Overview

        Calculating the flip angle (a.k.a. "tip" or "nutation" angle) for a particular spin that gives the maximal signal in the least amount of time when signal averaging over many transients (Ernst, 1966).

<center>37</center>

2.   Equation

   Ernst Angle = arccos (exp{-(TR)/(T1)}).

- TR- time in between pulses between RF pulses that repeat the pattern.

- T1- the longitudinal relaxation time of the spin.

3.   Screenshot
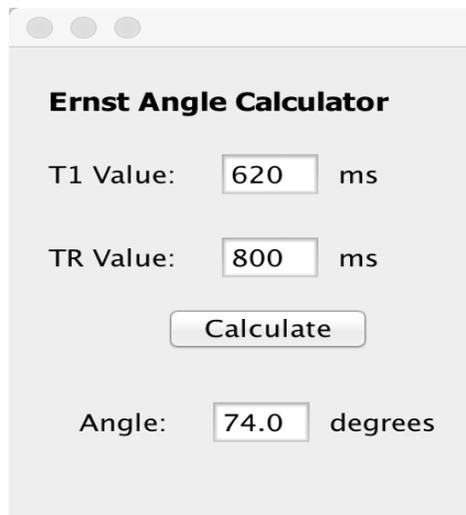
Figure 20. MR Ernst Angle Calculator

4.   Video link

   http://screencast.com/t/CAOmLjW46

4.3.6 MR Gradient Echo WM/GM Contrast Calculator

1.   Overview

   Calculating the contrast between white matter and grey matter under Gradient

Echo.

2.   Equation

   $S = k \, \rho \, (1-\exp(-TR/T1)) \, \mathrm{Sin}\theta \, \exp(-TE/T2^*) \, / \, (1 - \mathrm{Cos}\theta \, \exp(-TR/T1))$

- S is the amplitude of the signal in the frequency domain spectrum.

- k is a proportionality constant which depends on the sensitivity of the signal detection circuitry on the imager.

- T1, T2, and ρ are specific to a tissue or pathology.

3.   Screenshot

Figure 21. MR Gradient Echo WM/GM Contrast Calculator

4.   Video link

http://screencast.com/t/WVyigX4TX

4.3.7 MR Spin Echo WM/GM Contrast Calculator

1.   Overview

Calculating the contrast between white matter and grey matter under Spin Echo.

2.   Equation

S = k ρ (1-exp(-TR/T1)) exp(-TE/T2)

- S is the amplitude of the signal in the frequency domain spectrum.

- k is a proportionality constant which depends on the sensitivity of the signal

  detection circuitry on the imager.

- T1, T2, and ρ are specific to a tissue or pathology.

3.   Screenshot

Figure 22. MR Spin Echo WM/GM Contrast Calculator

4.   Video link

http://screencast.com/t/KTPgMqqV

4.3.8 MR Inversion Recovery WM/GM Contrast Calculator

1.   Overview

Calculating the contrast between white matter and grey matter under Inversion

Recovery, which is the time period between the initial 180° inversion pulse and the 90°

excitation pulse in an IR pulse sequence.

2.   Equation

$S = k \rho (1-2exp(-TI/T1)+exp(-TR/T1)) exp(-TE/T2)$

- S is the amplitude of the signal in the frequency domain spectrum.

- k is a proportionality constant which depends on the sensitivity of the signal

    detection circuitry on the imager.

- T1, T2, and ρ are specific to a tissue or pathology.

3.   Screenshot

Figure 23. MR Inversion Recovery WM/GM Contrast Calculator

4.   Video link

http://screencast.com/t/Rg6oBZaKUE

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<p style="text-align:center;"><u>4.3.9 CT Contrast Dosing Calculator</u></p>

1.   Overview

Calculating the CT contract dose volume and injection rate according to human's

body weight.

2.   Chart

<p style="text-align:center;">Table 3. Constant rate across weight groups using different dose volume for
different ages (Halls, 2014)</p>

Constant rate across weight groups using different dose volume for different weight groups							
Weight group	31-37kg	38-47kg	48-63kg	64-77kg	78-97kg	98-117kg	118+kg
Dose volume	60ml	70ml	80ml	100ml	120ml	140ml	160ml
Injection Rate	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s
Time needed to inject the Dose	23.1 secs	26.9 secs	30.8 secs	38.5 secs	46.2 secs	53.8 secs	61.5 secs
As you can see in the last row, the injection times would vary from 23 seconds to 61 seconds, if a fixed injection rate 2.6ml/sec were used. Such a large variation is not acceptable.							
Constant Time across weight groups using different dose volume for different weight groups.							
Weight group	31-37kg	38-47kg	48-63kg	64-77kg	78-97kg	98-117kg	118+kg
Dose volume	60ml	70ml	80ml	100ml	120ml	140ml	160ml
Injection Rate	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s	2.6ml/s
Time needed to inject the Dose	23.1 secs	26.9 secs	30.8 secs	38.5 secs	46.2 secs	53.8 secs	61.5 secs
As you can see in the last row, the injection times would vary from 23 seconds to 61 seconds, if a fixed injection rate 2.6ml/sec were used. Such a large variation is not acceptable.							
Different volumes and different delivery times of the contrast agent for different weight groups.							
Weight group	31-37kg	38-47kg	48-63kg	64-77kg	78-97kg	98-117kg	118+kg
Dose volume	60ml	70ml	80ml	100ml	120ml	140ml	160ml
Injection Rate	2.0ml/s	2.2ml/s	2.4ml/s	2.6ml/s	2.8ml/s	3.1ml/s	3.3ml/s
Time needed to inject the Dose							
These are the injection Rates that are actually used in the protocols.							

3.   Screenshot
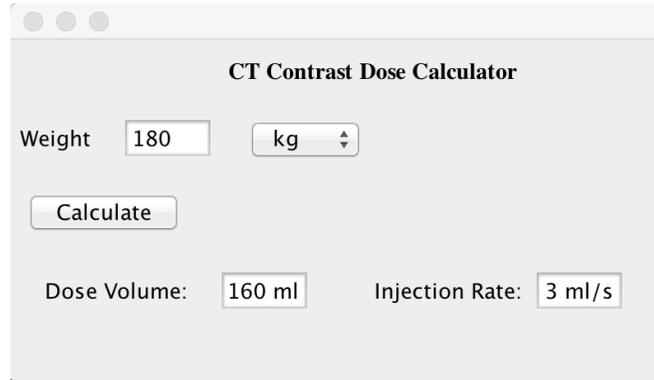
Figure 24. CT Contrast Dosing Calculator

4.   Video link

http://screencast.com/t/wVl1OHNAK5

4.3.10 CT /X-ray Actual Exposure Calculator

1.   Overview

Calculating the actual radiation dose of CT/X-ray exposure.

2.   Equation

Actual exposure $D = fX$

- $f = 0.87$ - (attenuation/density of material)/(attenuation/density of air)

- X is the initial exposure
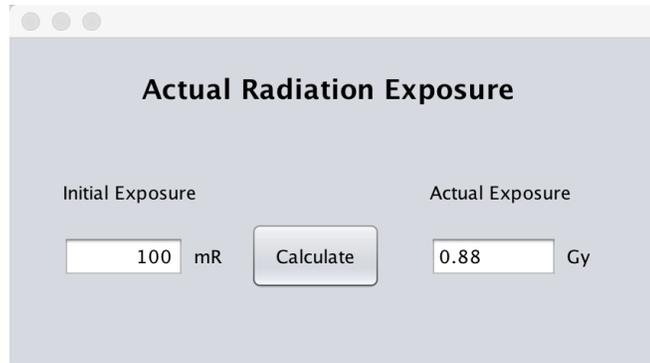
- $1R = 0.00876Gy = 0.87rad$

3.   Screenshot

Figure 25. CT /X-ray Actual Exposure Calculator

4.   Video link

http://screencast.com/t/6qggEbtl

4.3.11 CT Equivalent Calculator

1.   Overview

Calculating the equivalent dose is the effective dose of a case, in which the whole

body would actually absorb the same radiation dose.

2.   Equation

$H = DQ$, $D(\text{effective}) = \sum Hj*wj$; (uniformly)

- wj is the weighting factor for organ j —ICRP60 1997

3.   Chart

Table 4 Weighting factors for different tissues (UNSCEAR, 2008)

*The US Nuclear Regulatory Commission still endorses the ICRP's 1977 tissue weighting
factors in their regulations, in spite of the ICRP's later revised recommendations.

Organs	Tissue weighting factors		
	ICRP26 1977	ICRP60 1990	ICRP60 1997

Table 4 – continued

Gonads	0.25	0.20	0.08
Red Bone Marrow	0.12	0.12	0.12
Colon	-	0.12	0.12
Lung	0.12	0.12	0.12
Stomach	-	0.12	0.12
Breasts	0.15	0.05	0.12
Bladder	-	0.05	0.04
Liver	-	0.05	0.04
Oesophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Skin	-	0.01	0.01
Bone surface	0.03	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01
Remainder of body	0.30	0.05	0.12
Total	1.00	1.00	1.00

4.   Screenshot
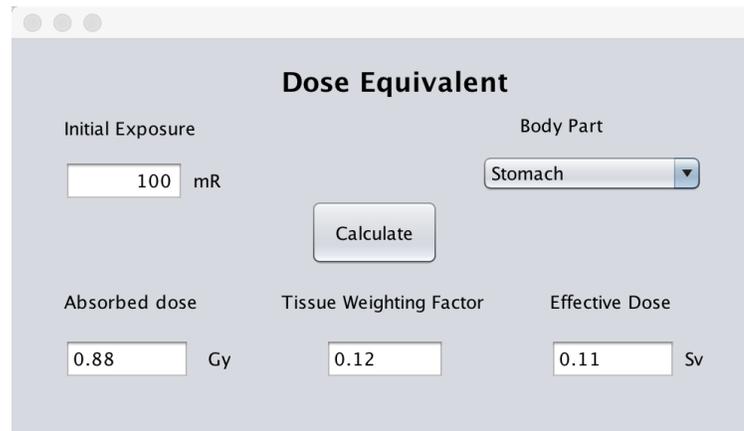
Figure 26. CT Equivalent Calculator

5.   Video link

http://screencast.com/t/DuFjbHKG9

<u>4.3.12 CT Number Calculator</u>

1.   Overview

     Calculating the CT numbers, which are sometimes expressed in 'Hounsfield units'.

The density assigned to a voxel in a CT scan on an arbitrary scale on which air has a

density −1000; water, 0; and compact bone +1000 (Miller & Keane, 1997).

2.   Equation

     CT number = 1000*(μmaterial-μwater)/μwater

- μ is the density of different materials

3.   Screenshot
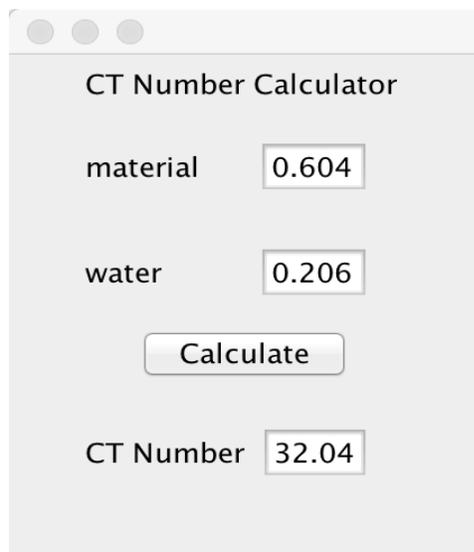
Figure 27. CT Number Calculator

4.   Video link

     http://screencast.com/t/d4qrngpHckV

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<u>4.3.13 CT Scan Time Calculator</u>

1.   Overview

Calculating the total time that is required to acquire all the data needed to produce

an image.

2.   Equation

Scan Time = C*R/(N*P*S)

- N = number of data channels

- R = rotation time for 360 degrees

- P = pitch; S = section thickness for each channel

- C = coverage in millimeters

3.   Screenshot

Figure 28. CT Scan Time Calculator

4.   Video link

<u>http://screencast.com/t/g6ucomfP</u>

4.3.14 CT Grid Ratio Converter Calculator

1. Overview

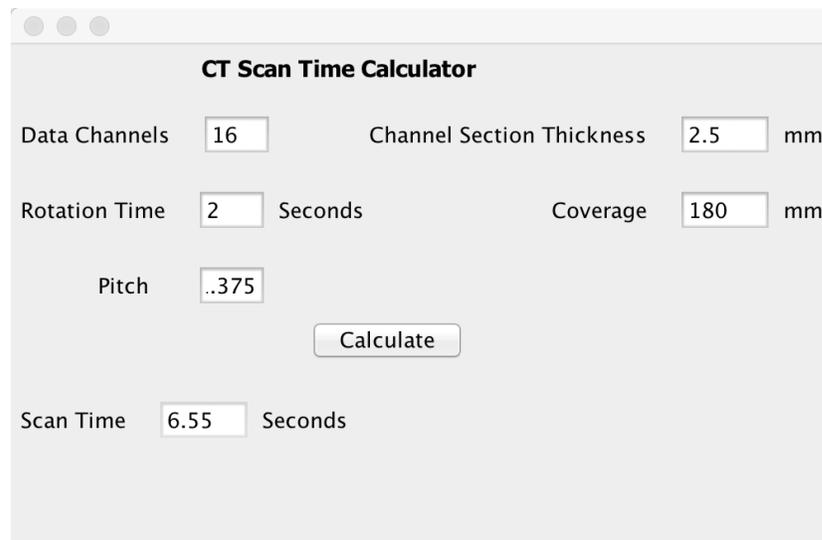Convert technique from one grid to another grid or from grid to non-grid and vice versa. This tool will allow the technologist to adjust technique if going from grid to non-grid or from one grid ratio to another.

2. Equation

Grid Ratio GCF (Grid Conversion Factors) (Johnston & Fauber, 2012)

5:1	2
6:1	3
8:1	4
12:1	5
16:1	6
No Grid	1

$$\frac{mAs1}{mAs2} = \frac{GCF1}{GCF2}$$

3. Screenshot

Grid Converter Calculator

Grid R...   6:1

Converted Grid Ratio   8:1   CONVERT

mAs Value   120   Converted mAs Value   160.0
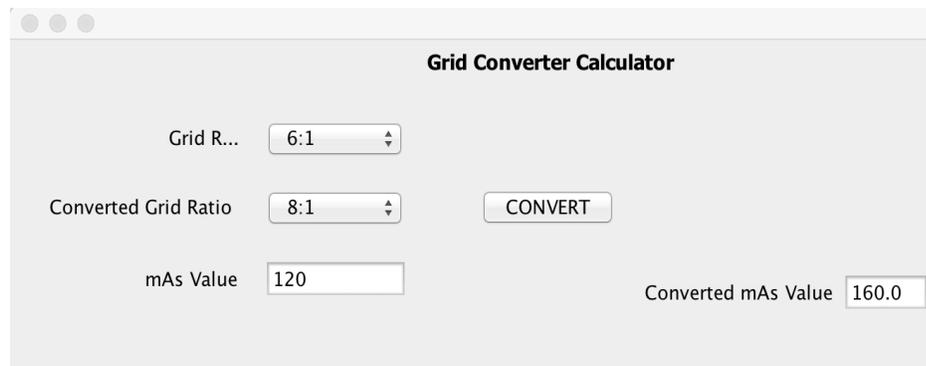
Figure 29. CT Grid Ratio Converter Calculator

4. Video link

http://screencast.com/t/gE7dICV8ix

4.3.15 CT Direct Square Law Formula for technique

change Calculator

1.   Overview

Determines new mAs necessary to maintain intensity of exposure if the distance is changed. This calculator is used to adjust mAs when a user changes from one distance to another. This calculator will adjust mAs to restore original intensity of the exposure from one distance to another.

2.   Equation

$$\frac{mAs1}{mAs2} = \frac{SID1}{SID2}$$

   • SID is the distance of optimal exposure achieved

3.   Screenshot
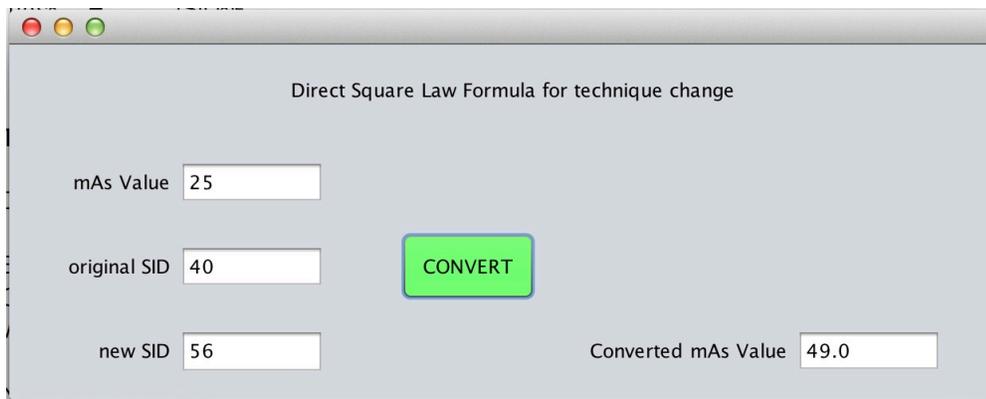
Figure 30. CT Direct Square Law Formula for technique change Calculator

4.   Video link

http://screencast.com/t/fW4rPm1IK

4.3.16 Half Life Calculator

1.   Overview

Calculating the time required for the decay of half of a sample of particles of a radionuclide or elementary particles.

2.   Equation

Half-life = ln(2)/decay constant

3.   Screenshot

Figure 31. Half Life Calculator

4.   Video link

http://screencast.com/t/TuRlkokwW4Xj

4.3.17 Ultrasound Pregnancy Gestation Calculator

1.   Overview

Calculating the fetus's length, weight and mass that based on the pregnancy gestation period table.

2.   Chart

Table 5. Average fetal length and weight chart (Doublet. et al., 1997)

Gestational age	Length (US) (crown to rump)	Weight (US)	Length (cm) (crown to rump)	Mass (g)
8 weeks	0.63 inch	0.04 ounce	1.6 cm	1 gram
9 weeks	0.90 inch	0.07 ounce	2.3 cm	2 grams
10 weeks	1.22 inch	0.14 ounce	3.1 cm	4 grams

Table 5 – continued

11 weeks	1.61 inch	0.25 ounce	4.1 cm	7 grams
12 weeks	2.13 inches	0.49 ounce	5.4 cm	14 grams
13 weeks	2.91 inches	0.81 ounce	7.4 cm	23 grams
14 weeks	3.42 inches	1.52 ounce	8.7 cm	43 grams
15 weeks	3.98 inches	2.47 ounces	10.1 cm	70 grams
16 weeks	4.57 inches	3.53 ounces	11.6 cm	100 grams
17 weeks	5.12 inches	4.94 ounces	13 cm	140 grams
18 weeks	5.59 inches	6.70 ounces	14.2 cm	190 grams
19 weeks	6.02 inches	8.47 ounces	15.3 cm	240 grams
20 weeks	6.46 inches	10.58 ounces	16.4 cm	300 grams
20 weeks	10.08 inches	10.58 ounces	25.6 cm	300 grams
21 weeks	10.51 inches	12.70 ounces	26.7 cm	360 grams
22 weeks	10.94 inches	15.17 ounces	27.8 cm	430 grams
23 weeks	11.38 inches	1.10 pound	28.9 cm	501 grams
24 weeks	11.81 inches	1.32 pound	30 cm	600 grams
25 weeks	13.62 inches	1.46 pound	34.6 cm	660 grams
26 weeks	14.02 inches	1.68 pound	35.6 cm	760 grams
27 weeks	14.41 inches	1.93 pound	36.6 cm	875 grams
28 weeks	14.80 inches	2.22 pounds	37.6 cm	1005 grams
29 weeks	15.2 inches	2.54 pounds	38.6 cm	1153 grams
30 weeks	15.71 inches	2.91 pounds	39.9 cm	1319 grams
31 weeks	16.18 inches	3.31 pounds	41.1 cm	1502 grams
32 weeks	16.69 inches	3.75 pounds	42.4 cm	1702 grams
33 weeks	17.20 inches	4.23 pounds	43.7 cm	1918 grams
34 weeks	17.72 inches	4.73 pounds	45 cm	2146 grams
35 weeks	18.19 inches	5.25 pounds	46.2 cm	2383 grams
36 weeks	18.66 inches	5.78 pounds	47.4 cm	2622 grams
37 weeks	19.13 inches	6.30 pounds	48.6 cm	2859 grams
38 weeks	19.61 inches	6.80 pounds	49.8 cm	3083 grams
39 weeks	19.96 inches	7.25 pounds	50.7 cm	3288 grams
40 weeks	20.16 inches	7.63 pounds	51.2 cm	3462 grams
41 weeks	20.35 inches	7.93 pounds	51.7 cm	3597 grams
42 weeks	20.28 inches	8.12 pounds	51.5 cm	3685 grams

3.   Screenshot
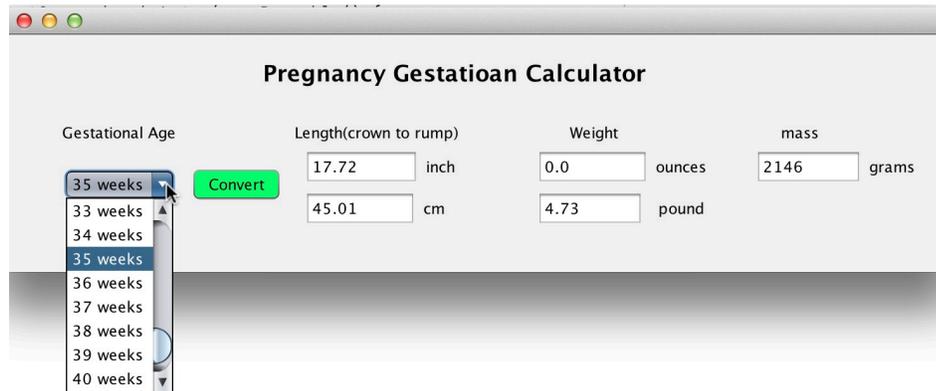
Figure 32. Ultrasound Pregnancy Gestation Calculator

4.   Video link

http://screencast.com/t/R8wfgkTE

CHAPTER 5

SUMMARY AND DISCUSSION

Chapter 5 summarizes the motivation, rationale and current development of RP Import and Modality calculators. It also discusses the future prospect of these two applications.

RP Essential, an online medical imaging protocol management platform, is the core product of Radiology Protocol. Its successive application RP Import has proven to be a great support for enhancing the performance of RP Essential in three ways: improving the user experience, reducing the time of data import process and saving human labor. RP Import was designed and developed in four phases: DICOM convert, DICOM import, DICOM select and the integration process. The main function of RP Import is to selectively convert one DICOM file per series to XML file, and import DICOM elements from the XML files into the MySQL database.

Since RP Import is the interface between users and the Radiology Protocols' protocol management platform, in the further development, RP Import is expected to have the following abilities:

a) Ability to associate a DICOM image to its corresponding protocol information

b) Ability to export DICOM file to thumb drive for importing into the scanners

c) Ability to convert a new protocol to a DICOM file and export such file

d) Ability to override any Imported DICOM tags

e) Ability to extract compressed DICOM folders

f) Ability to activate whenever RP submission server detects DICOM files

g) Ability to be modified into a command-line driven program stored in the Linux box

Other than these new features, RP Import should also have a more elaborate process to allow users customize the database and edit DICOM tags. Such process starts by

1) Selecting an existing database or build a new database. Once an existing database has been chosen, or a database has been created, the user need to first decide the DICOM Meta Data Architecture – the layout of the protocol table, in order to import DICOM elements. This process is called the Database/Protocol User Input, which provides the structure that all of the DICOM information relies on being properly inserted into the MySQL tables.

2) Adding protocols to such database. Once all of the Database/Protocol User Input requirements have been done, the users can now upload the DICOM files to extract the DICOM elements information. DICOM elements are being selected or edited during this process.

3) Adding additional DICOM information to an existing protocol. Radiology Protocols is trying to employ an open source project named Cornerstone to associate DICOM images to the corresponding protocol information.

Modality Calculators is a series of calculation GUIs that are used to compute a number of important medical parameters associated with various modalities. It was designed to be an assistant tool for modifying protocols. The purpose of developing Modality Calculators is to improve the precision in determining the dosage of certain medical parameters, which has great impact for RP Essential on fulfilling its mission to

provide medical guidance for producing appropriate protocols. Currently, the designs of

Modality Calculators are still going through Quality Assessment process and have not yet

been rolled into a product yet. In the future development, calculators will not only cover

more medical parameters, but also provide a warning system that indicates specifications

should be associated with the calculators. Therefore, Modality Calculators should be

embedded with both the algorithm and medical dosage guidance. For example, if a T1-

weighted MR image has a short TR but long TE sequence (T1-weighted image usually

has a short TR and short TE sequence), the warning system should notify user with such

specification.

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