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## **Automated retrieval of radiotherapy data for clinical trials, audit and research.**

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## Abstract

*Objectives:* To enable fast and customisable automated collection of radiotherapy data from tomotherapy storage.

*Methods:* Human-readable data maps (TagMaps) were created to generate DICOM-RT data from tomotherapy archives, and provided access to "hidden" information comprising delivery sinograms, positional corrections and adaptive-RT doses.

*Results:* 797 datasets totalling 25,000 scans were batch-exported in 31.5 hours. All archived information was restored, including the data not available via commercial software. The exported data were DICOM-compliant and compatible with major commercial tools including RayStation, Pinnacle and ProSoma. The export ran without operator interventions.

*Conclusions:* The TagMap method for DICOM-RT data modelling produced software that was many times faster than the vendors solution, required minimal operator input and delivered high volumes of vendor-identical DICOM data. The approach is applicable to many clinical and research data processing scenarios and can be adapted to recover DICOM-RT data from other proprietary storage types such as Elekta, Pinnacle or ProSoma.

*Advances in knowledge:* A novel method to translate data from proprietary storage to DICOM-RT is presented. It provides access to the data hidden in electronic archives, offers a working solution to the issues of data migration and vendor lock-in, and paves the way for large-scale imaging and radiomics studies.

## 1 Introduction

Collection and harmonisation of RT data for clinical trials, quality assurance (QA) and research purposes is a non-trivial task that requires integration of numerous software systems and data types [1], [2], [3]. The retrieval pipeline includes un-archiving, restoration on clinical databases, manual selection via graphical user interface (GUI) and re-archiving. The complexity of the process frequently leads to errors and incomplete restores. Older data may no longer be readable and accumulate in "data graveyards". The VoxTox study [4] study includes 873 patients treated with helical tomotherapy between 2007-2017. The data exceed 300,000 files archived in several proprietary formats. To collect and harmonise these data with minimal impact on clinical workflow, we developed a framework to

translate proprietary-formatted data into the DICOM-RT objects RT-Plan, RT-Structure Set, RT-Image and RT-Dose. We also enabled access to the information “hidden” in patient archives, e.g., not available for conventional DICOM export [5]. The method can be adapted to translate other vendor data formats into DICOM-RT to suit the purposes of different centres.

## **2 Materials and Methods**

Similar to other vendors such as Pinnacle, ProSoma and Elekta, TomoTherapy© electronic archives comprise structured text and raw data (detector sinograms, planned fluence, images and voxel doses). We developed the data translation software following the analysis, collection, modelling, software implementation and testing cycle stages described below.

### **2.1 Analysis of vendor storage formats**

TomoTherapy patient archives comprise files in the Extensible Markup Language (XML) that hold RT treatment and meta-data, and binaries containing the imaging, dose and detector data stored as “<UID>.img/bin/dpe” files [6], [7]. Data fragments in XML master-files are linked via DICOM unique identifiers (UIDs). Three major versions of storage formats were identified. The only version-related change in raw data formats was observed in the plan sinogram storage versions 3.xx/4.xx. Imaging, detector and dose data were stored unmodified, with the exception of the plan CT images. The latter were re-shaped a) following the insertion of the tomotherapy couch and b) during the DICOM export.

### **2.2 Data collection**

A database of 20 patients treated between 2008-2012 was established to cover all storage formats and transformation scenarios. The database included the electronic vendor archives from two tomotherapy units, the vendor-exported DICOM-RT as well as the positional corrections manually recorded by the treatment radiographers.

### **2.3 Modelling**

To translate vendor storage into DICOM-RT, we created a collection of XML files termed “TagMaps”. Each TagMap listed the DICOM tags for

one DICOM-RT type. The TagMaps were created using the `dcm2xml` utility from the `dcm4che2` DICOM toolkit [8]. Tag contents were set to contain queries to locate the corresponding data in the vendor storage using XPath 2.0 language [9]. We tested the queries using the `XMLTools` Notepad++ plugin.

DICOM sequences such as *ReferencedImageSequence* contain many elements with identical structures. Therefore, it is sufficient to model only one element per sequence, and to use it as a template. The number of the elements to be generated was derived from a dedicated tag. The algorithm is described in A.

Three sets of TagMaps were produced to map the storage versions 3.xx, 4.0 and 4.2+. The TagMaps were based on the vendor’s DICOM Conformance Statement [10].

## 2.4 Implementation

The software to read user inputs, locate the patient data, run XPath queries and write the DICOM-RT objects was implemented in Java 1.7 (Fig. 1). The `dcm4che2` toolkit was used to generate DICOM objects from TagMaps.[8]

A collection of DICOM classes derived from the parent class `DicomObject` was created to handle object-specific raw data transformations (Fig. 2). The raw data transformations included type conversions, reshaping, splitting and arithmetic manipulations. These transformations can be a) implemented in the translation software or b) encoded in TagMaps. We performed simple transformations such as centimetre-to-millimetre conversions in the TagMaps, and offloaded more complex manipulations such as image padding into the corresponding DICOM classes.

### 2.4.1 Plan CT export

During treatment planning, the image of the diagnostic scanner couch on the planning CT is replaced by the tomotherapy couch image. To incorporate the tomotherapy couch image into the planning CT, vertical and horizontal image padding may be necessary. Using the DB defined during the mining stage, we reverse-engineered the padding algorithm and implemented it in the `RTImage` class, generic to all RT-Image objects.

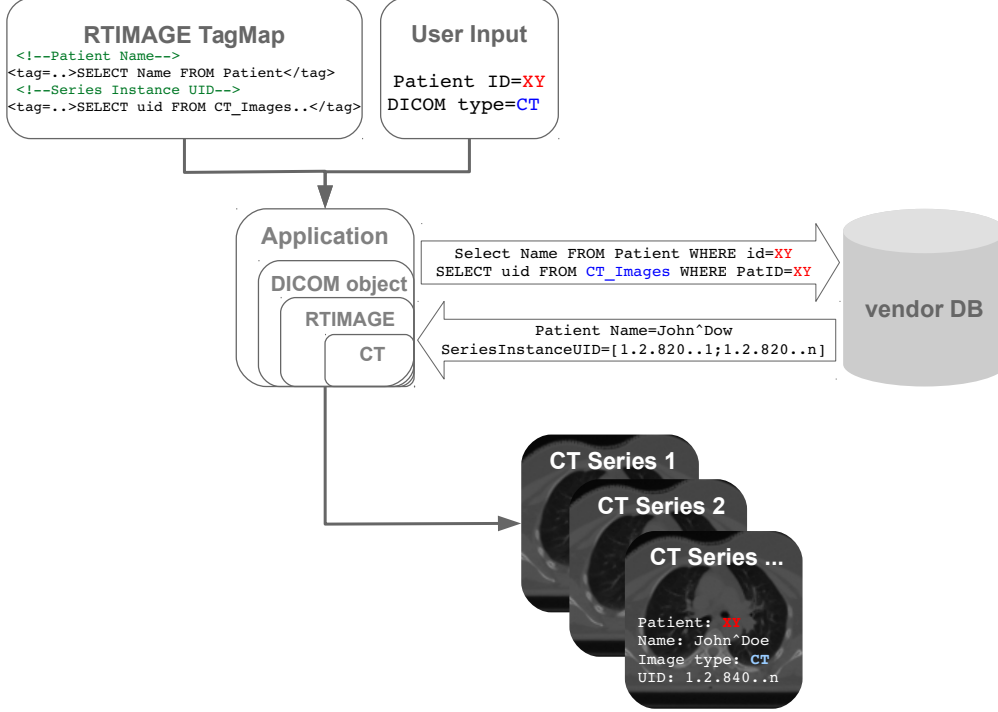


Figure 1: Generation of DICOM-RT objects using TagMaps. The application receives user input to retrieve CT data for patient XY and uses the RTIMAGE TagMap to generate a new DICOM object. At this stage, the DICOM object contains the queries to the vendor storage. The application then executes the queries on the vendor storage and overwrites the DICOM object with the retrieved data. The resulting DICOM objects are saved as DICOM CT image series.

#### 2.4.2 RT-Dose export

Tomotherapy dose data are stored as voxel doses in gray in 32-bit floating point format. The exported RT-Dose converted dose values to 16-bit integers using scaling factors (SFs) to reduce the file size.

$$D_{16} = \frac{D_{32}}{\text{SF}} \quad (1)$$

The SFs can be defined arbitrarily, provided that the precision is preserved between conversions. We defined the SF as the ratio of the maximum voxel dose and the maximum of the 16-bit integer number range.

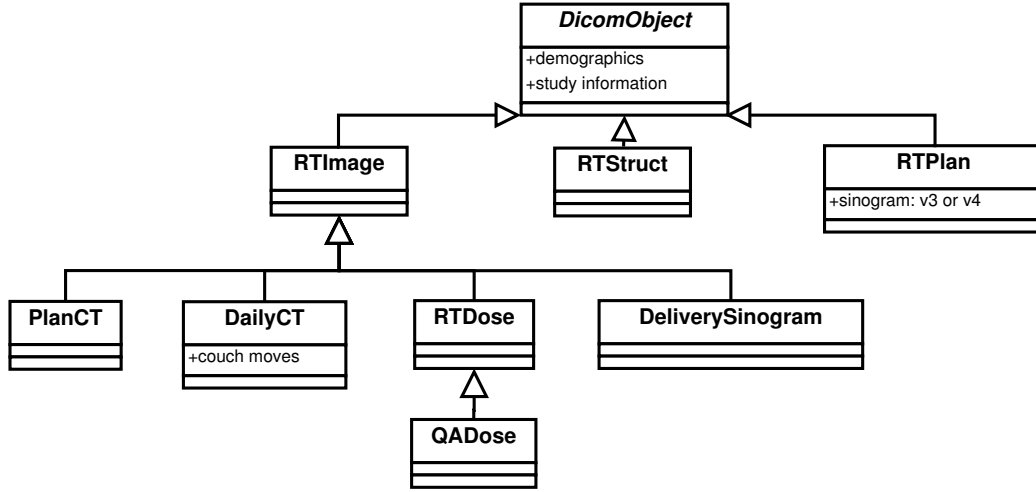


Figure 2: DICOM object hierarchy in the application.

### 2.4.3 Plan sinogram

Plan sinograms are sequences of multi-leaf collimator (MLC) opening times for each gantry/couch position (“Control Point” (CP) or “projection”), stored as fractions of MLC-open-time/CP. The sinogram storage underwent significant changes between 3.xx and 4.xx: while 3.xx stored sinogram data as MLC-open-time/CP, v. 4.xx stored open-leaves-only cumulative MLC opening times for each leaf. The data types changed from `float` in 3.xx to `double` in 4.xx. To handle 3.xx/4.xx sinogram formats, we implemented a private class `PlanSinogram` encapsulated in the `RTPlan` class. `PlanSinogram` automatically detects and converts 3.xx and 4.xx storage to the DICOM-RT-Plan format.

### 2.4.4 Export of hidden data

The data described in this section are not included in the vendor-exported DICOM-RT.

**Patient position corrections following image guidance** The corrections in the couch/gantry positions during the image-guidance (IG) are essential for image registration, QA and audits. In the tomotherapy storage, the corrections are linked to the corresponding IG scan via a UID in the *fullCorrelationDataArray* fragment (Sec. 2.1). If the communication between the treatment unit and the database is disrupted, the corrections are recorded, but the linking is lost. To re-link the data, we defined a

fallback procedure that located the IG scan using timestamps. The exported corrections were included into the IG-MVCT scans as private tags.

**Adaptive Radiotherapy Dose** PlannedAdaptive® software allows dose re-calculation on daily IG-MVCT scans to assess dose differences arising from changes in patient’s anatomy. However, the re-calculated doses are available only for visual inspection on tomotherapy workstations. To access the re-calculated voxel doses, we defined a QADose type based on DICOM RT-Dose. The QADose data were used to validate the dose calculation software.

**Delivery sinogram** During a treatment delivery, the tomotherapy imaging detector is recording a signal that is stored as an average value per projection for each detector channel. These “delivery sinograms” provide valuable information for in-vivo dosimetry and QA [11]. Although from 2014 commercial software exists to analyze the delivery sinograms [12], it suffers from the same limitations as other GUI-based tools and is unsuitable for automated data analysis.

An RTIMAGE-based TagMap was created to restore the delivery sinograms. The exported sinograms have been used in the department’s QA procedures. Methods for in-treatment dose monitoring using comparison of planned and delivered sinogram data are under development.

## 2.5 Testing

The exported DICOM data were compared to their vendor-exported counterparts and imported into several commercial and freeware tools. The exported position corrections were compared to the treatment radiographers manual records. For the performance testing, RT-Plan, RT-Dose, CT and MVCT data for five patients were exported using a) our software and b) PlanningStation®. Our software was run on a Dell Precision with 3.3 GHz Intel Xeon CPU and 8 GB RAM. Identical network locations for the input and output data were used for both export methods.

## 3 Results

### 3.1 DICOM-RT export

Fig. 3 (I-III) demonstrates transformations of a plan CT image following the couch replacement. We reproduced the changes in the image

dimensions for all modification scenarios (no change, vertical/horizontal/vertical+horizontal enhancements). The data exported using our algorithm were identical to the vendor exports. The RT-Plan objects were correctly

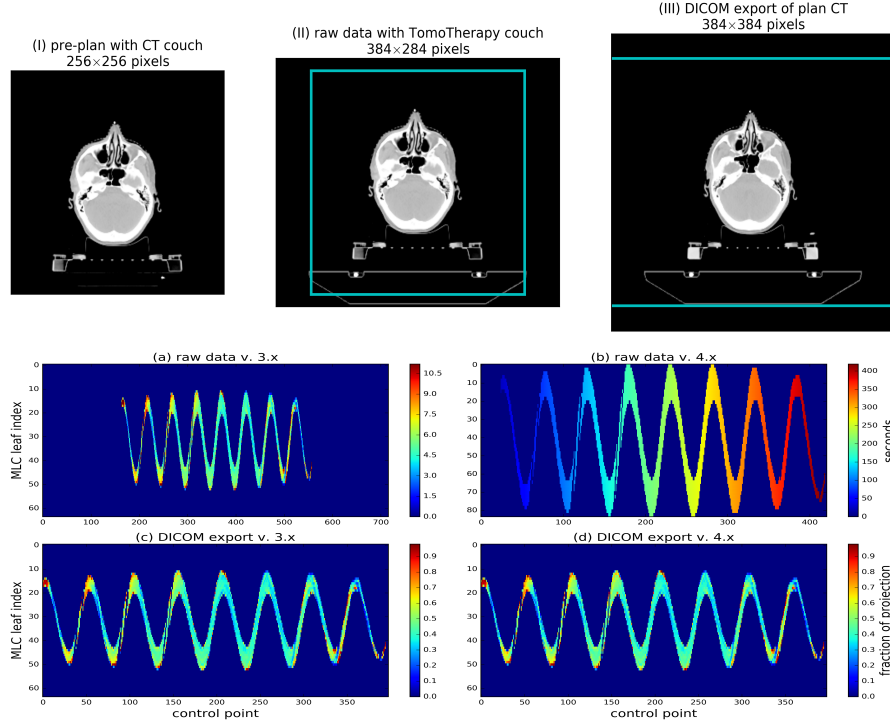


Figure 3: Transformations of binary data for the DICOM export.

**I-III:** Insertion of the treatment machine couch image into the plan CT. (I)  $256 \times 256$  CT image with CT scanner couch; (II) treatment couch is inserted, the image is enhanced to  $384 \times 284$  pixels to incorporate a larger couch image with preservation of the treatment isocenter; (III) for DICOM export, the image is padded to  $384 \times 384$  pixels. Cyan lines in (II) and (III) mark the image area inherited from the previous processing step.

**a-d:** Sinogram export in vv 3.xx (a,c) and 4.xx (b,d). a), b): raw data in vendor storage. b), d): RTPLAN Tomo Projection Sinogram Data tag (300D, 10A7). Raw data for v.4.x (b) show leaf opening and closing times for the MLC leaves open during the treatment (MLCs 11 to 52); the sinogram height is *number of open leaves*  $\times$  2. The entries for leaves 1-10 and 53-64, that are closed for the entire treatment duration, are not recorded. The left hand-side of (b) depicts 10 second beam warm-up time.

restored for both underlying binary formats (Fig. 3 a-d). The TagMap- and



vendor-exported RT-Doses showed differences of  $\pm 0.001\%$  of the maximum dose. These were expected from the number rounding during the format conversions (Sec. 2.4.2).

### 3.2 Performance

The mean export time/dataset using PlanningStation was  $15 \pm 7$  minutes per treatment unit, with 10 minute preparation and 5 minutes of “pure” DICOM export time. Our framework required  $30 \pm 5$  seconds for DICOM export, and 1-2 minutes for the automated data lookup, generation of input files and output QA. The retrieval was automated and ran without operator supervision. The data exported using our software included IG positional corrections (Sec. 2.4.4) that were used to re-calculate the delivered radiation doses.

### 3.3 Automated data retrieval

We extracted 797 patient data sets including over 25,000 daily scans. The retrieval took 31.5 hours and ran as a background task concurrent with the routine workload. All archived data was successfully recovered. 88% of the restored datasets were complete; 12% needed additional processing due to missing archives. The average time to process one dataset including creation of text input files, DICOM-RT generation, export, network transfer from the archived storage and testing was  $2 \pm 0.5$  minutes per patient.

### 3.4 DICOM conformance

Apart from the insignificant dose differences (Sec. 3.1) and private tag enhancements (2.4.4), the DICOM-RT datasets exported using our software were identical to the tomotherapy exports, and preserved the UID links between the files. The generated DICOM-RT were tested and accepted in the clinical and research software packages summarised in Tab. 1.

## 4 Discussion

Compared to the vendor’s DICOM-RT export, our software was more than 10 times faster. We attribute this to the use of state-of-the-art software libraries and bypassing the internal conversions in the vendor software. The exported DICOM-RT objects were correctly linked and compatible with a number of RT software tools. We found that some software packages

	CT	MVCT	RT-Plan	RT-Dose	RT-Struct
ProSoma 3.3	+	+	n/a	+	+
Pinnacle 9.8	+	+	n/a	+	+
OnQ RTS	+	+	n/a	+	+
RayStation 3.5	+	+	n/a	n/a	+
Mirada Medical XD3	+	+	n/a	n/a	+
DCMTK 3.6.0-15	+	+	+	+	+
Dicompyler	+	+	+	+	+
ImageJ	+	+	n/a	+	n/a
CheckTomo	+	+	+	+	+

Table 1: Compatibility of extracted DICOM data with commercial and open-source software. ProSoma software removed the StudyTime tag during the import.

\*: Image data was accepted in Explicit LittleEndian transfer syntax only.

may alter the contents of DICOM objects during import/export, and recommend thorough testing for each DICOM-RT type and software package to avoid data losses or corruptions.

The standardised and customisable nature of the extracted DICOM-RT data make the mapping software a useful tool in clinical RT trials.

However, validation must be performed to ensure that the extracted data are identical to those extracted using trial-approved methods. Examples of such validation are given in Sec. 3.4 and Tab. 1.

While this work was focussed on the translation of tomotherapy storage, the method can be generalised to handle other storage types (B) including relational databases. MOSAIQ oncology information system (OIS) stores data in a Structured Query Language (SQL) database. Example 1 presents a TagMap that locates the RT-Treatment Record data in the MOSAIQ-DB using SQL queries.

Code Example 1: RT-Treatment Record TagMap for MOSAIQ 2.64. Table and column names are altered. The evaluation is performed in stages: first, all studies associated with a patient are found; then all study series are located; then the RTPLAN object linked to the series is located.

```

<dicom>
<!--Patients Name-->
<attr tag="00100010">SELECT FIRST_NAME, LAST_NAME FROM Patient WHERE
Patient.ID=?</attr>
...
<!--Study Instance UID-->
<attr tag="0020000D">SELECT S.StudyInstanceUID FROM DCMStudy S INNER JOIN
Patient P ON P.Pat_ID1 AND P.ID = ?</attr>

```

```

...
<!--Series Instance UID-->
<attr tag="0020000E" vr="UI">SELECT SeriesInstanceUID FROM DCMSeries D WHERE
D.DCMStudy_ID = ?</attr>
...
<!--Referenced RT Plan Sequence-->
<attr tag="300C0002" vr="SQ">
  <item>
    <!--Referenced SOP Class UID (constant value)-->
    <attr tag="00081150" vr="UI">1.2.840.10008.5.1.4.1.1.481.5</attr>
    <!--Referenced SOP Instance UID-->
    <attr tag="00081155" vr="UI">SELECT PlanInstanceUID FROM TreatmentList T
    WHERE T.ID = ? AND T.ImageSeriesUID=? </attr>
  </item>
</attr>
</dicom>

```

Following the process described in Sec. 2, the application would generate a blank DICOM file from the TagMap, establish the connection to MOSAIQ database and populate the DICOM object by evaluating the SQL queries. In our experience, the software development and data mapping require 3-12 months, depending on the existing documentation and expertise, while updates and addition of new data types take from a few hours to a few days. We consider this time investment worthwhile. The mapping software can retrieve incomplete or historic datasets, provides enriched information about the RT treatment (Sec. 2.4.4), and future-proofs the patient data by converting it from proprietary formats into the DICOM-RT. The latter is of particular value for radiomics applications, as these require large volumes of standardised imaging data to build reliable models [13].

## 5 Conclusions

The TagMap framework to translate tomotherapy electronic archives to customised DICOM-RT objects is described. The framework enabled access to the “hidden” data including IG positional corrections, delivery sinograms and “adaptive-RT” doses. We restored historic data incompatible with the current vendor software. To our knowledge, this is the first implementation of large-scale automated retrieval of tomotherapy data.

TagMaps provide human-readable data models that can be changed on-the-go to alter the data selection criteria or to add/remove contents to the exported DICOM-RT data. Such flexibility is impossible to achieve in the commercial environment, due to long feedback loops between users and developers, and to the complexity of software development under the Medical Device Directive [14].

The method can be used as a customisable alternative to vendor software

for DICOM-RT export, as well as a standalone tool to collect the data disseminated across multiple locations and stored in various formats.

## References

- [1] T. Skripcak, C. Belka, W. Bosch, C. Brink, T. Brunner, V. Budach, D. Büttner, J. Debus, A. Dekker, C. Grau, S. Gulliford, C. Hurkmans, U. Just, M. Krause, P. Lambin, J. A. Langendijk, R. Lewensohn, A. Lühr, P. Maingon, M. Masucci, M. Niyazi, P. Poortmans, M. Simon, H. Schmidberger, E. Spezi, M. Stuschke, V. Valentini, M. Verheij, G. Whitfield, B. Zackrisson, D. Zips, and M. Baumann, “Creating a data exchange strategy for radiotherapy research: Towards federated databases and anonymised public datasets,” *Radiotherapy and Oncology*, vol. 113, no. 3, pp. 303–309, 2014.
- [2] T. Nyholm, C. Olsson, M. Agrup, P. Björk, T. Björk-Eriksson, G. Gagliardi, H. Grinaker, A. Gunnlaugsson, A. Gustafsson, M. Gustafsson, *et al.*, “A national approach for automated collection of standardized and population-based radiation therapy data in Sweden,” *Radiotherapy and Oncology*, vol. 119, no. 2, pp. 344–350, 2016.
- [3] P. Mayles, A. Nahum, and J.-C. Rosenwald, *Handbook of radiotherapy physics: theory and practice*. CRC Press, 2007.
- [4] N. G. Burnet, J. Scaife, M. Romanchikova, S. Thomas, A. Bates, E. Wong, D. Noble, L. Shelley, S. Bond, J. Forman, *et al.*, “Applying physical science techniques and CERN technology to an unsolved problem in radiation treatment for cancer: the multidisciplinary ‘VoxTox’ research programme,” *CERN IdeaSquare Journal of Experimental Innovation*, vol. 1, no. 1, p. 3, 2017.
- [5] M. Y. Law and B. Liu, “DICOM-RT and Its Utilization in Radiation Therapy 1,” *Radiographics*, vol. 29, no. 3, pp. 655–667, 2009.
- [6] A. Ryczkowski and T. Piotrowski, “Tomotherapy archive structure and new software tool for loading and advanced analysis of data contained in it,” *Reports of Practical Oncology & Radiotherapy*, vol. 16, no. 2, pp. 58–64, 2011.
- [7] T. Bray, J. Paoli, C. M. Sperberg-McQueen, E. Maler, and F. Yergeau, “Extensible markup language (XML),” *World Wide Web Consortium Recommendation REC-xml-19980210*. <http://www.w3.org/TR/1998/REC-xml-19980210>, vol. 16, p. 16, 1998.

- [8] M. J. Warnock, C. Toland, D. Evans, B. Wallace, and P. Nagy, “Benefits of using the DCM4CHE DICOM archive,” *Journal of Digital Imaging*, vol. 20, pp. 125–129, 2007.
- [9] M. Kay, *XPath 2.0 programmer’s reference*. John Wiley & Sons, 2004.
- [10] “TomoTherapy DICOM Conformance Statement Hi-Art Treatment System v5.0.,” October 2016.
- [11] L. L. Handsfield, R. Jones, D. D. Wilson, J. V. Siebers, P. W. Read, and Q. Chen, “Phantomless patient-specific TomoTherapy QA via delivery performance monitoring and a secondary Monte Carlo dose calculation,” *Medical physics*, vol. 41, no. 10, p. 101703, 2014.
- [12] E. Mezzenga, E. Cagni, A. Botti, M. Orlandi, and M. Iori, “Pre-treatment and in-vivo dosimetry of Helical Tomotherapy treatment plans using the Dosimetry Check system,” *Journal of Instrumentation*, vol. 9, no. 04, p. C04039, 2014.
- [13] R. J. Gillies, P. E. Kinahan, and H. Hricak, “Radiomics: images are more than pictures, they are data,” *Radiology*, vol. 278, no. 2, pp. 563–577, 2015.
- [14] A. Höss, C. Lampe, R. Panse, B. Ackermann, J. Naumann, and O. Jäkel, “First experiences with the implementation of the European standard EN 62304 on medical device software for the quality assurance of a radiotherapy unit,” *Radiation Oncology*, vol. 9, no. 1, p. 1, 2014.

## A Sequence generation using TagMaps

In the DICOM objects that contain sequences, the sequence templates defined in TagMaps (Sec. 2.3) are generated using algorithm 1.

---

**Algorithm 1** Creation of sequences of arbitrary length from a single TagMap entry.

---

```
procedure CREATE_SEQUENCE(template)  
  new_element  $\leftarrow$  template.first_element  
  new_sequence  $\leftarrow$  empty_sequence  
  #Fetch sequence data from database  
  db_data  $\leftarrow$  template.get_data_list  
  n_elements  $\leftarrow$  db_data.length  
  for i = 1 : n_elements do  
    i-th_element = new_element.deep_copy  
    #Populate the i-th element's contents  
    new_element  $\leftarrow$  Controller.evaluate(db_data[i], i - th_element)  
    new_sequence.add(new_element)  
  end for  
  return new_sequence  
end procedure
```

---

The corresponding DICOM-RT class, f.e., RTSTRUCT, contains methods to evaluate each sequence. The sequence generation methods a) locate and process the TagMap entry to determine the number of elements to generate, b) create an empty sequence element c) populate the empty element with the data from the vendor storage and d) add the element to the sequence. The steps *c* and *d* are repeated, until all sequence data are processed.

## B TagMap production

To create a TagMap for a DICOM-RT type, we first generated an XML representation or “stub” of the desired type using `dcm2xml` utility from the `dcm4che2` DICOM toolkit [8]. Then, the contents of each tag in the stub file were replaced by the XPath queries to locate the tag content, such as scan acquisition date, inside a TomoTherapy patient archive. Alternatively, an empty stub file can be created from scratch using the vendor’s DICOM Conformance Statement for reference.

## B.1 TomoTherapy RTDOSE TagMap

The RT-Dose TagMap fragment (Ex. 2) illustrates four data access methods:

1. *direct selection* implemented in the tag *Patient's Name*. The patient's name is stored in an XML node *patient*, sub-node *briefPatient*, and sub-sub-node *patientName*. This method is applicable when the location XPath is unique.
2. *conditional selection* is used to select one data element by its features. It is demonstrated in the private tag *Dose Cube Description*, where the XPath query returns only the volume descriptions with the label "Opt\_Dose\_After\_EOP" (optimized dose after end of planning).
3. *text substitution* is applied when tag contents do not vary, e.g. the *Manufacturer* tag. These tags were set to the values specified by the tomotherapy Conformance Statement.
4. *fragment evaluation* is shown in the tag *Slice Thickness*, where the hash ('#') character indicates that the data mapping will be run only on a selected fragment of the archive. The fragment selection is encoded in the tag *Dose Cube Description*, which is removed from the exported DICOM object after evaluation.

Code Example 2: A simplified TagMap fragment for tomotherapy v4.xx.

```
<!--Patients Name-->
<attr tag="00100010">//patient/briefPatient/patientName</attr>

<!--Manufacturer = CONSTANT-->
<attr tag="00080070">tomotherapy Incorporated</attr>

<!--Dose Cube Description.-->
<attr tag="00990099">//doseVolumeList[imageType='Opt_Dose_After_EOP']</attr>

<!--Slice Thickness-->
<attr tag="00180050">#arrayHeader/elementSize/z*number(10)</attr>

<!--Referenced Image Sequence-->
<attr tag="00081140">
  <item>
    <!--Referenced SOP Class UID = CONSTANT-->
    <attr tag="00081150">1.2.840.10008.5.1.4.1.1.2</attr>

    <!--Referenced SOP Instance UID-->
    <attr tag="00081155">//plannedStructureSet/*/modifiedAssociatedImage</attr>
  </item>
</attr>
```

## B.2 Pinnacle RTDOSE

TagMaps can be used to translate any vendor storage into DICOM-RT, provided the storage structure is understood well. Ex. 3 shows an RT-Dose TagMap fragment for Pinnacle® Treatment Planning System v9.8. Pinnacle stores text data as “label=value” pairs optionally grouped into sections. The text and raw data for one patient are stored as files in a single folder.

The data assembly from multiple files is implemented using the *file* attribute associated with each DICOM tag. So, the *Slice Thickness* tag is populated from the subsection “DoseGrid” of the “Plan.Trial” file, and multiplied by the factor 10 to convert centimetres to millimetres, while the tag *PatientID* is mapped to the “PatientID” entry in the “Patient” file.

Code Example 3: Simplified fragments of RT Dose TagMap for Pinnacle 9.8.

```
<dicom>
  <!--Specific Character Set = CONSTANT-->
  <attr tag="00080005">ISO_IR 100</attr>

  <!--Instance Creation Date-->
  <attr tag="00080012" file="Plan.PlanInfo">TimeStamp</attr>

  <!--Patient ID-->
  <attr tag="00100020" file="Patient">PatientID</attr>

  <!--Slice Thickness-->
  <attr tag="00180050" file="Plan.Trial">(DoseGrid .VoxelSize .Z)*10</attr>

  <!--Study ID-->
  <attr tag="00200010" file="ImageSet_0.ImageSet">StudyID</attr>

  <!--Series Number-->
  <attr tag="00200011" file="plan.Trial">SeriesNumber</attr>
</dicom>
```