

A New Software for Patient Dose Extraction and Assessment from CT DICOM Images

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ARTICLE INFO	ABSTRACT
Article type: Original Paper	Introduction: Radiation dose monitoring is an important objective of radiation safety and quality assurance program. The purpose of this study was to develop an automated approach for monitoring and estimating patient radiation doses from Computed Tomography (CT) examinations. Automated software, based on MATrix LABORatory (MATLAB) environment, was introduced for extracting and analyzing patient dose identifiers from Digital Imaging and Communications in Medicine (DICOM) CT image files. In addition, an estimation of effective dose and statistical studies were implemented.
Article history: Received: Dec 09, 2021 Accepted: July 17, 2022	Material and Methods: A random sample of 1466 patients' CT DICOM image files were collected from a 64-slice Siemens' Somatom Perspective CT scanner. The proposed Graphical User Interface (GUI) extracts the volumetric CT dose index (CTDI _{vol}), the dose length product (DLP) for each phase of scan session in order to calculate the patient radiation effective dose (E). A graphical layout presenting statistical values was also produced, according to study date, patient sex, and CT protocol type.
Keywords: Computed Tomography Radiation Dose Monitoring Automatic Dose Extraction Diagnostic Reference Levels	Results: The GUI performance was verified according to the manually proceeded results. The extraction speed and accuracy of the radiation dose values were satisfactory, as compared to the approaches presented in literatures such as optical character recognition (OCR) technology, and the direct extraction from the metadata of CT image files. Conclusion: The proposed GUI performs the extraction of CT patient dose metrics CTDI _{vol} , DLP with a satisfactory speed and accuracy. The obtained results could be shown in numerical and graphical formats, and it could be used for radiation dose monitoring and Diagnostic Reference Levels (DRLs) establishing purposes with multiple filtering capacities.

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Introduction

Computed Tomography (CT) becomes one of the main tools in the medical examination due to its accuracy and adequate quality for medical diagnosis [1]. Despite its benefits, the patients undergoing CT examinations may receive a relatively high ionizing radiation dose, which may cause negative health effects [2]. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report of 2000, radiation patient CT doses represent about 50% of the medical radiation exposure [3]. The periodic and continuous assessment of the patient's radiation doses seems to be mandatory.

As the principal product of the "DICOM Standards Committee", the DICOM (Digital Imaging and Communications in Medicine) file formulation standard is also used to form the CT images files, which provides an extremely rich support for storing, not only the image matrix pixels but also other important data about imaging modality, and also radiation metric identifiers [4,5].

Several techniques have been developed for extracting the radiation dose metric identifiers from CT dose reports. The "Optical Character Recognition, OCR" technique [6,7] is one of these techniques, but it encountered some difficulties in the automatic recognition process of some characters. In addition, only visual information presented on the CT monitor was able to be extracted. Dave and Gingold [8] proposed a direct access and extraction of data from DICOM dose report file using "MATrix LABORatory (MATLB) Image Processing Toolbox", which may help to eliminate errors obtained when applying OCR technology.

With the purpose of optimizing the patient radiation protection a "Graphical User Interface" (GUI) based on MATLAB environment, was developed in order to automatically extract radiation dose identifiers from CT dose report file included in the CT image DICOM format. The proposed graphical interface is able to calculate the effective dose and perform several associated statistical processes. Therefore, it could be used to evaluate the CT patient

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dose and help establish a local CT diagnostic baseline. Furthermore, it could be characterized by simplicity and competitiveness in the speed of data extraction.

Materials and Methods

This study was conducted using a set of 1466 patient CT images DICOM files obtained from the 64-slice Siemens' Somatom Perspective CT scan machine located at Al-Bayrouni University Hospital in Damascus, SYRIA for a period of 9 months. The patient's CT image directories have been manually stored on an external storage media from the CT Picture Archiving and Communication System (PACS). The patient weight and height were also recorded in order to classify the patients, according to the Body Mass Index (BMI) into normal-, over-, or underweight groups. RadiAnt DICOM viewer(2022.1 (64-bit)) [12] was used to open DICOM files.

The graphic interface was designed using the MATLAB environment (R2019a), which is divided into three main sections: Data Viewer section, Data Analysis

section and Control section. Figure 1 shows the flowchart of the proposed algorithm.

Data Viewer section

Through this section, the user provides the path of the patients DICOM folder generated by the CT scanner. The patient information and radiation dose metric identifiers can then be extracted from the corresponding dose report file, and displayed in a dedicated table which includes: Patient's name, Patient's ID, Patient sex, CT Protocol, Examination date, Dose length product (DLP)-Premonitoring (mGy*cm), DLP-Monitoring (mGy*cm), DLP venous (mGy*cm), CT Dose Index (mGy), and Dose Length Product Total (mGy*cm). The patient effective dose (mSv) was calculated by multiplying the DLP_{total} with the appropriate K factor as presented by The International Commission on Radiological Protection (ICRP) report 102 [9]. Figure 2 shows a sample of patient extracted data (The patient's names were masked for privacy reasons).

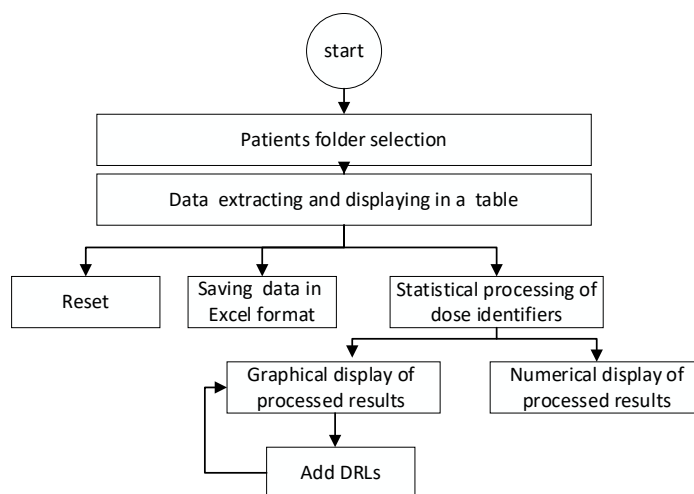


Figure 1. Flowchart of the proposed GUI to extract the patient dose from CT DICOM image files.

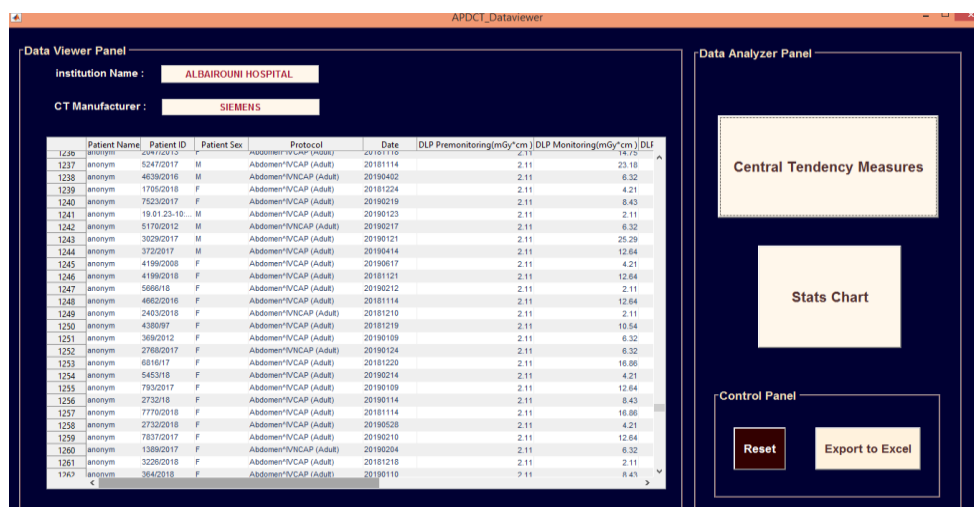


Figure 2. The main window in this GUI shows the "Data viewer" which displays extracted information and shows the other two panels: Data Analyzer and Control.

Data Analysis section

The Data analysis section, represented in the data analyzer panel, displays the calculated statistical values (average, standard deviation, and upper quartile) for the radiation dose metrics: Volume CT Dose Index (CTDI_{vol}), DLP_{total} and E, in a numeric format, with the possibility of applying filters according to the patient sex and/or examination protocol. The "ICRP 135" recommends that the DRL should be calculated as an upper quartile of dose quantities [10]. Figure 3 shows an example of the calculated results. In addition, the calculated values can also be displayed in a graphical format into two ways: either as a "Box Plot" to show the average value, upper quartile, lower quartile and outliers

for every dose metric, or as a "Bar graph" to show the upper quartile values for the previous calculated dose metrics with filtering possibility. Figures 4 and 5 show an example of the two graphical output options respectively. Furthermore, a proposed diagnostic reference level (DRL) values can also be inserted into the graphical window for comparison purposes as illustrated in Figure 6.

Control section

The control section is used to export and save the generated database table in an Excel format file. It permits also to reinitialize the generated table to receive a new patient folder.



Figure 3. The window used to calculate the central tendency measures (average, standard deviation, and upper quartile) for CTDI_{vol}, DLP, and E.

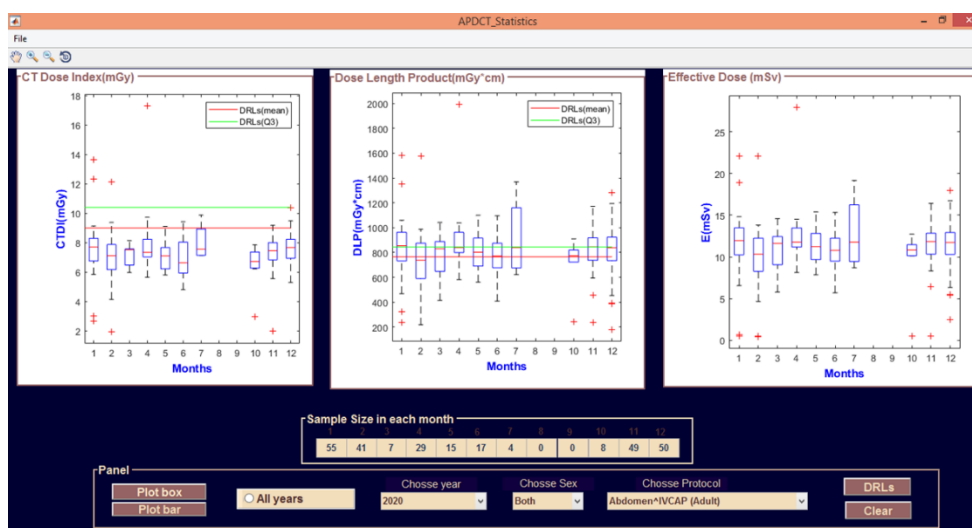


Figure 4. The window, which displays the result of processing as box plots.



Figure 5. The window, which displays the result of processing as bar.

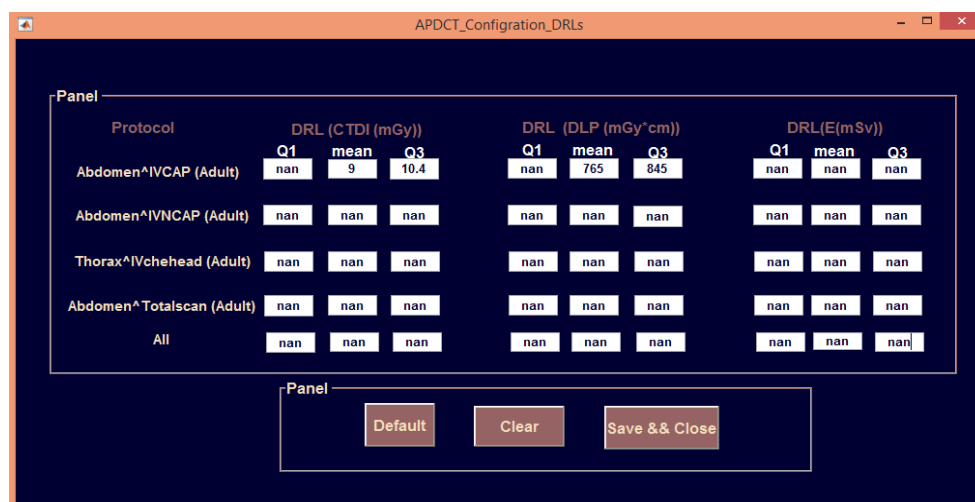


Figure 6. The window through which any DRLs values could be inserted.

Results

A randomized sample of 1466 of CT DICOM image files for adult patients was included in this study. The following CT protocol was noticed in this sample: Abdomen^IVCAP, Abdomen^IVNCAP, Thorax^IVchehead, Abdomen^Totalscan, where IV indicates the use of contrast media during imaging to enhance the contrast of soft tissues, N for neck, C for chest, A for Abdomen, P for pelvis, Thorax^IVchehead for head imaging (in this study), and Abdomen^Totalscan for trunk and head imaging (in this study).

Figures 2 through 6 show an example of a processed patient's folder, scanned by CT using the Abdomen^IVCAP (Adult) protocol via the designed GUI. The resulting extracted patient data is displayed in the database table, and the statistical values are displayed numerically and graphically. The graphically displayed data was also compared with the Foley et al DRLs values [11]. These values were inserted through the

dedicated DRL configuration insertion window, in order to plot them on the graphical representation as shown in figures 4 and 5 (red and green lines).

The execution time for the studied sample of patients CT DICOM image files was 11 minutes with an accuracy of 100%, using a personal computer (PC) equipped with an Intel (R) Core (TM) i5-2430M processor @ 2.40 GHz, 4 GB random access memory (RAM), running on Microsoft Windows 8 64-bits operating system. The obtained patient data was also saved in an EXCEL file format. Figure 7 shows a comparison between manually processed data from seven patients using Excel data sheet (Microsoft Office Professional Plus 2013) and the processing of the same data using our designed GUI. The comparison confirms the accuracy of the extracting and calculation algorithms.

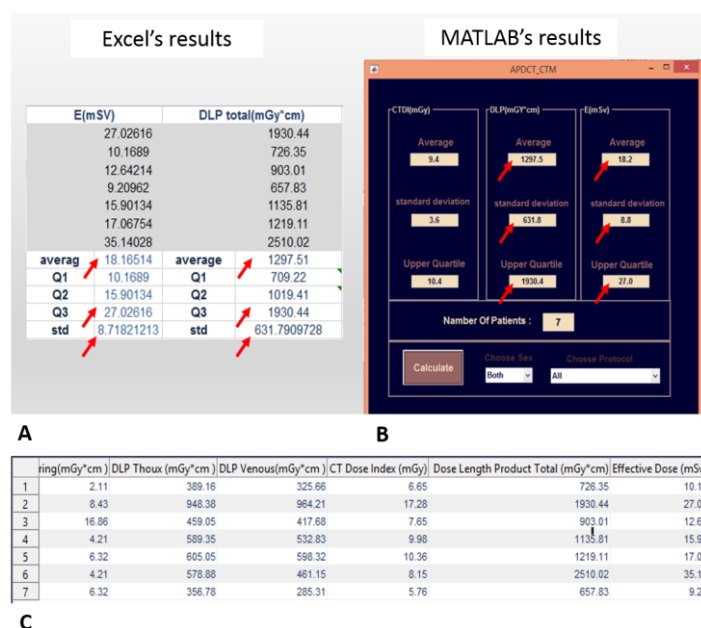


Figure 7. Comparison between the calculated values for a sample of 7 patients. A: shows the manually entered data of seven patients and their processing using EXCEL sheet. B: results of MATLAB processing for the same sample size. C: the values displayed in the data viewer panel in MATLAB.

Discussion

The proposed GUI attempts to address some of the challenges in other extractive approaches. In the OCR extraction technique, the overall accuracy of the DLP calculation was 100%, but the accuracy of the CTDI and DLP calculation for the scanning strings' chain was only 95%, due to split-text errors. In addition, the total DLP was not shown in approximately 60% of the dose report images, and there were a few typing errors [6].

According to Dave and Gingold work [8], more accurate results can be obtained by estimating and extracting CT dose indexes and related imaging identifiers, directly from the data stored in DICOM report files. They tagged and extracted DICOM Dose Report files from Picture Archiving and Communication Systems (PACS), isolating errors inherent in the OCR method and reaching 100% accuracy. All images have been recovered from PACS to a folder on a local hard drive before executing the program, and applied to a sample of 64 CT patients DICOM files, and their obtained results then were verified manually as compared to their Dose Report images. The extracted data took 4 minutes 50 seconds using a personal computer with Microsoft Windows XP PC with a Central Processing Unit (CPU) clock speed of 2.99 GHz and 3.24 GB of RAM.

In this study, the RadiAnt DICOM viewer(2022.1 (64-bit)) [12] was also used to display DICOM CT images, and to access the various image DICOM tags including patient information and radiation dose identifiers. The previously extracted data using the proposed GUI were re-extracted manually from the DICOM tag for verification purposes, thus, an EXCEL file was created and the patient height and weight were

inserted in order to calculate the BMI "body mass index" value.

The evaluation of the performance of the proposed graphical interface in comparison with the other techniques presented in the previous studies [6-8], shows several advantages in terms of precision and speed. The accuracy of Excel and the extracted data was 100 percent. The timely process of extracting and displaying data was competitive with previous extracting approaches. Moreover, the proposed GUI could be used to keep the medical physicist informed about patient radiation doses. It could be useful for carrying out survey studies in the medical institute on a continuous basis in order to contribute to the establishment of a CT diagnostic reference level.

The proposed method was tested with CT images generated by the Somatom 64 slice Siemens Perspective CT scanner. However, minor changes are necessary to implement the CT images of other scanners. Furthermore, another direct dose extraction plan from the PACS is under development which correlates with ongoing investigations [13].

Conclusion

An automatic software for radiation dose metrics extraction and patient dose assessment using DICOM CT images was presented. The proposed GUI performs statistical calculations from the extracted CTDI_{vol} and DLP values, and represents the results in numerical and graphical forms with multiple filtering options according to the study date of, patient sex, and imaging protocol. The proposed graphical interface demonstrates 100% accuracy with competitive extraction and processing speed compared to previous associated approaches. It can also be used to establish the local reference diagnostic level for Computed Tomography.

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