ABSTRACT

Our study involves mainly patient’s immobilization and imaging in conformal radiotherapy process. The goal is the accurate automatic determination of the patient’s reference point in regard to table coordinates, which is very important for the successful execution of the whole treatment, as patient’s set up must be literally maintained between imaging and treatment phase. The significance of the determination of the reference point, emerge in the treatment phase for the accurate  transfer of the planned irradiation technique to the patient. The determination of RP to table coordinates is based mainly on detection of markers on patient’s skin and in table in a DICOM image, generated during the imaging process. The results are compared with the same results acquired manually by a tape measure and by the use of commercial software for 3D simulation of external beam radiation therapy.

KEY WORDS
Radiotherapy, image processing, patient’s set-up
sticks, which are visible in CT image. The table contains three metallic sticks along its length. Each stick has 30mm distance from the other. All technical characteristics of the table are shown in Figure 1. In this way someone can accurately calculate the exact position of a slice on the table by the number and structure of visible sticks.

The determination of RP uses the CT slice in DICOM image format [5,6], produced during imaging, which includes all three markers on patient body, as in Figure 2. The white arrows show the three markers on patient’s skin, which define the RP point of the patient. The yellow circles present the three upper table markers. Under these markers there should be a number of lower markers regarding the position on the table.

3. Implementation

The calculation of the RP to Table coordinates is the most important process in this study. There are currently two different ways supported, to calculate the RP to table point (Figure 3). Manually by user determination of the CT table markers and RP point and automatically, by user bounding and automatic determination of CT markers and RP point. The exact coordinates \((x, y, z)\) of RP location on table’s coordinate system are calculated as follows:

\[
X = X_{RP} - X_M
\]
\[
Z = \text{abs}(Y_{RP} - \text{Average}(Y_L, Y_M, Y_R)) - \text{offset}
\]
\[
Y = -(N-1) \times 400 - d
\]

, where
The Y coordinate is the same for all points since all points are defined in the same CT image (slice).

The automatic way of RP location in table’s coordinate system calculation utilizes a CT markers’ detection algorithm, which follows (Figure 5):

**Table CT markers:**
The table has two rows of markers capable of accurately determining CT slice’s position on the table. Upper markers are always three: left, middle, and right. Lower markers can differ in number from 1 to 4 in respect to the position on the table.

**Patient CT markers:**
CT markers on patient’s skin can easily determine the reference point.
This algorithm can detect all CT markers contained in a user defined region. It is based on low level image characteristics (Hounsfield values) and location information. The detection of CT table markers, except a window of Hounsfield values, calculates also other specific characteristics as their number, which can be between 4 and 7, and their relative position. All Hounsfield values of CT images were retrieved directly from the DICOM files.

The detection of the RP point takes also into account that these CT markers should be placed on patient’s body, so they should be the top-, left- and right-most points. The markers detection algorithm takes as input an HU value and its half range. The automatic calculation of table CT markers and RP point is based on markers’ HU. Because these values can differ from image to image, user can set a window of HU values, which better detect the markers on each image. User can configure separately HU value and half range for table markers and RP point marker.

All above algorithms were implemented in C++ and were integrated into the Anticollision, Registration and Information System for Radiation Therapy (ARIS) software [7].

4. Evaluation

In the framework of the presented study, measurements about the position of 28 patients were taken in different ways, in order to compare their differences and reliability. The measured value is the location of RP in table’s coordinate system in Cartesian coordinates.

At first the RP location was measured manually on the CT table by a tape measure. Then it was calculated manually on Exomio [8] using appropriate measurement tools provided by the software and finally using ARIS both in manual and automatic mode. The differences of the above results are shown in the following graphics:

It is quite obvious that the mean values of the differences in RP location in the table coordinate system between ARIS and Exomio are below 1mm, which is considered a very accurate estimation. Manual calculation with tape measure is the most inaccurate as expected, because of the various practical limitations e.g. the patient’s set-up on the table. It is also very important that the mean value of the difference of the three coordinates of RP between the two modes of ARIS is below 1mm. This means, that the automatic calculation of RP to table coordinates is not only easier and more user friendly, but also very accurate and reliable.

The differences between manual tape measurements and Exomio are quite great as expected, with averages of 1.70mm, 2.44mm and 1.93mm for axes X, Y, Z respectively. The average value of difference between Exomio and ARIS automatic mode is 0.86mm, 0.79mm and 0.93mm for axes X, Y, Z respectively.

4. Conclusion

This approach presents a different way of estimating the RP location in table’s coordinate system. The advantage of this method is that it offers an automatic and easy interface; it can be easily integrated in radiotherapy
process and can provide reliability not only in imaging, but also in radiation treatment phase.

Our future work includes the combination of this study with a patient 3D model produced by a 3D camera during imaging and treatment phases for patient’s set up verification (computer-aided set-up). The 3D camera will be mounted on the ceiling on both rooms of CT and accelerator and will produce patient 3D model. Markers visible from the camera will be placed on the table and patient’s skin. The exact position of 3D model on the CT table will be specified utilizing the above method and all movements regarding the initial position will be easily calculated.

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References:


