An Innovative Approach for Radiation Centre Identification and Its Applications in Filmless QA for Static MLC and Stereotactic Isocentre.

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**Introduction**

On the subject of the way the dose calculation algorithms handle the radiation field boundaries and its centre, the commercially available radiotherapy planning systems are in common with the following aspects:

- The radiation field centre is the origin of a 2D or 3D dose matrix.
- For a regular symmetric radiation field, the radiation centre is assumed to be at the halfway between each two parallel edges.
- An asymmetric regular radiation field can be identified by the distances between its edges [X1, X2, Y1 and Y2] and its radiation centre.
• A conformal radiation field can be defined by means of the coordinates of the MLC-tips positions in a Cartesian coordinate system in which the radiation centre is taken as the origin.

• The radiation centre is always coincident with the mechanical centre of the gantry, collimator and couch rotations, which is assumed to be unique for all possible combinations of these rotations.

Accordingly, a precisely localized radiation centre can be regarded as the reference point for the inspection of the radiation field boundaries and mechanical centre of the machine.
THE AIM

The aim of the present work is to develop a method for radiation centre localization on an EPID panel and use it as the origin of a coordinate system which can be used to find out the distance to any object on the imager from the radiation centre. This can be used for the following applications.

1. Analyzing EPID images of MLC-defined radiation fields so the MLC tips position can be determined, and subsequently be compared with expected MLC files from the planning system.

2. Measuring the distances between the radiation centre and an object on the imager represents the mechanical centre when the machine is set up in different gantry and couch rotations.
METHOD

1. A narrow field was designed to allow the interleaves radiation leakage of the two central leaves only, as the other leakages were shielded by the normal jaws.

2. An ARIA plan was created and a star test was performed by taking EPID images of this narrow field with different collimator rotations (0, 45, 90, and 315).

3. The EIPD images were exported in a text format to Matlab in which each two images were overlapped individually and the maximum dose point in each combination is assumed to be radiation centre location. The maximum deviation between the individual maxima did not exceed the pixel spacing so that the average position was found to be a sufficient approach to get the “initial radiation centre”,
4. A 10 x 10 MLC field was created to correct for the probable misalignment between the imager pixel columns and the MLC-sides edge at the zero collimator rotation.

5. A geometrical method has been introduced for the determination of the collimator-imager misalignment angle theta as follow:

\[ \Delta Y = Y_{11} - Y_{12} \]
\[ \tan \theta = \Delta Y / 2d. \]

Where \( d \) is half the distance between the initial radiation centre and the field edges in the x-direction, and \( Y_{11} \) and \( Y_{12} \) are the distances between the midpoints to the field edges in the y-direction. Therefore, finding the distances \( d \), \( Y_{11} \) and \( Y_{12} \) requires an edge detection tool.

A Matlab edge function was employed for this purpose, which detects the edges at the points where the dose gradient is maximum.

Note: This method cannot be applied unless the initial radiation centre is known.
5. Rotating the set of the star images by theta and repeating overlapped images analysis so a new radiation centre called "The Radiation centre base line (RCBL)" was obtained.

"Since the initial radiation centre is not necessarily to be the same as the geometrical centre of the imager, an image rotation of theta would relatively rotate the initial radiation centre by an angle of minus theta."

To overcome this, it was necessary to proceed our method with the following two steps:

6. Applying the geometrical approach to the oriented 10 x 10 MLC image and the RCBL to verify the expected zero theta value after orientation.

At this point the intended coordinate system has been defined by means of: (1) The RCBL as an origin, and (2) the angle theta as a mandatory orientation angle to fit any image to the coordinate system prior analysis.
7. Converting the measured distances with EPID in pixels to length unit.

- A set of reference MLC fields have been created with symmetric number of opened leaves in both sides of the field centre.
- A fitting formula is created on the bases of the relationship between the lengths in pixel, from EPID, against the MLC side to side distances, from the TPS, so it can convert distances from pixels to length unit.

The advantage of this method is when the fitting of field sizes in this direction be replaced by a single correction factor. Thereafter, the set of and reference MLC fields were replaced by the 10x10 MLC field only.
8. **Dealing with the length measurement precision**

The length accuracy measurement with EPID depends on the pixel spacing, which is limited by the cassette design. A spacing of about 0.4 mm is the minimum pixel spacing in a commercially available EPID so far.

To overcome that, an enhancement of the number of the points in the image by means of a 2D-**interpolation image processing** took place.

In effect the 2D linear interpolation was found to be sufficient for this purpose for the following reasons:

i. The pixel spacing of the original image is considerably small.

ii. Our region of interest in the analysis is the penumbra region, where the dose profile is almost linear.
Furthermore, the same interpolation processes is applied to every image imported to the system, so the RCBL, the angle theta, the fitting formula, and all the analysis are performed consistently.

Because of a current computer memory issue, a maximum number of 6 images can be analysed at once with a calculation accuracy of 0.15 mm, both can be increased with a more computational power machine.
Application I: Static MLC QA.

1. Extracting leaves positions

- A collimator angle of zero was found to be the best angle to allow a number of control points to be selected symmetrically in both sides of the RCBL along the beam direction to be observed by the imager, after the expected leaf positions.
- An image sample of half the expected leaf thickness was taken at each control point. The number and spacing of these points are obviously depend on the MLC design and the source to imager distance (SID).
1. **Extracting leaves positions (continue)**

- The edge function was applied for each image sample individually.

- The mean distance in pixels from each of the two detected edges to the RCBL were converted to distance in cm so as to give the positions of the expected pair of leaves of banks A and B at that control point.

- A 2D array is created to occupy each leaf name, position and the related image in a systematic arrangement so it can be compared with the corresponding leaves positions from the MLC file that was imported earlier from the TPS to Matlab.
The outcome of the code was presentation graphically with the detected leaves positions and names, and the field shape overlapped with the EPID image.
2. **Dealing with the abnormal cases:**

- If only one edges is detected at any sample, the code will consider the other tip to be outside of the detection panel. However, if there is no edges is detected, the code will assume the leaf pair are either outside the radiation panel or the sample is fully shielded by one of them. In both occasions a warning message will appear with the appropriate meaning.

- If one or more of the leaves tips are shielded by one or more of normal jaws, the code will not consider these leaves.

The normal jaws locations are obtained automatically from the header of the EPID image so the shielded leaves numbers, the jaw name and the corresponding image number can be specified, and a warning message with this meaning will come out to the user.
Application II: Stereotactic Isocenter Inspection.

1. As previously a coordinate system on the EPID panel was defined by the RCBL and the angle theta together with the open 10 X 10 MLC field as a reference field for pixel spacing calibration factor can be used as a start point in this application.

**NOTE:** The coordinate system should be redefined as the gantry angle changes, since the relative position of the radiation centre significantly changes due to the EPID sagging.

2. The BrainLab radio opaque sphere was aligned to the laser at the collimator, gantry and couch angles of interest, and an EPID image was taken for the sphere.

3. In Matlab, the edge function was applied to the image and the position of sphere centre (C) was determined by means of a Matlab centroid function.

4. The distance between the point C and the RCBC represents the shift between the mechanical and radiation centers of the machine with this particular set up parameters.
The testing procedure and its results have been put aside from this presentation as the allowed time is limited.
Conclusion:

A new method for radiation centre base line identification with EPID is developed and tested with Matlab. The approach was based on the fact that central leaves sides locations are fixed and reproducible without any calibration requirement. The method is found to be working correctly for static MLC QA and machine isocentre check.
Thank you.