New Pixel-based Algorithm to Correct Non-uniform Response of Radiochromic Film Scanners

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1. Introduction

Radiochromic films are used for dose mapping in various radiation therapy modalities including external beam radiation therapy, stereotactic radiosurgery, and brachytherapy [1,2]. A critical aspect of radiochromic film dosimetry is the accurate readout of the scanner without dose distortion [3,4]. Most of charge-coupled device (CCD) scanners used for the radiochromic film dosimetry tasks, however, use a fluorescent lamp or a cold-cathode lamp as a light source, which results in a significant amount of light scattering in the active layer of the film. The effect of the light scattering creates non-uniform response even for a uniformly exposed film, leading to a dose distortion [5,6].

In the present study, a new algorithm was developed to correct the dose distortion of a flat-bed scanner, with a GUI-based software for use in clinical practice.

2. Methods and Materials

2.1 Non-uniform response curve

The evaluation of the non-uniformity of the scanner requires measured beam profiles at various dose levels. The films were, therefore, irradiated from 0 cGy to 307.1 cGy. The Gafchromic[@] EBT radiochromic films placed inside a polystyrene phantom were perpendicularly irradiated by a 6 MV photon beam produced from a Varian 6EX linear accelerator. The exposed films were then scanned by a flat-bed Epson 1680pro scanner, and the background doses were subtracted from the results. Because the non-uniformity of the scanner was significant only in the horizontal direction, the horizontal profiles configured with the pixel values were analyzed, as shown in Fig. 1.

It was found that the pixel values monotonically decrease in the horizontal direction, from the center to the edge-sides of the scanner, for all of the exposed doses. In addition, the difference between the maximum and the minimum pixel values gradually increases with dose. Therefore, it is necessary to correct the distortion of dose values by appropriately considering the non-uniform response properties of the scanner.

2.2 Development of Dose Correction Algorithm

The EBT films were analyzed to develop a method to correct the dose distortion of the scanner. Especially, the response of the scanner at different dose levels was investigated as a function of the pixel position as shown in Fig. 2. The solid line indicates the ideal case where the scanner reading values matches the irradiated doses. It can be seen that the pixel responses at the central position of the scanner are very close the ideal values, whereas those at the edge-sides are significantly different from the ideal values. The difference also increases with irradiated doses.

A GUI-based user-friendly software with aforementioned was developed with MATLAB[TM] as shown in Fig. 3. This front panel of this software is composed of three major regions, i.e., data import, calibration, and conversion. The main function of the first regions is to import the raw film data and pixel values; the next region performs the film calibration from the pixel values to doses; and the correction algorithm is finally applied in the last region.

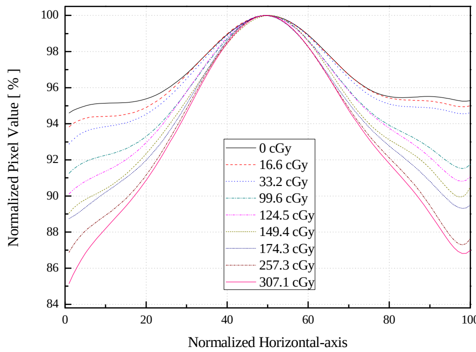

FIG. 1. Normalized Pixel Values Related with Irradiated Doses Ranging from 0 cGy to 307.1 cGy

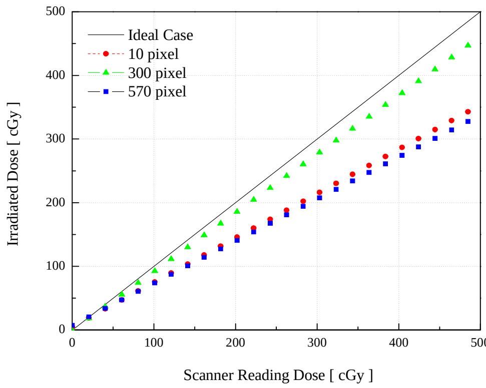

FIG. 2. The Scanner Responses Curve for the Irradiated Doses as a Function of the Pixel Position

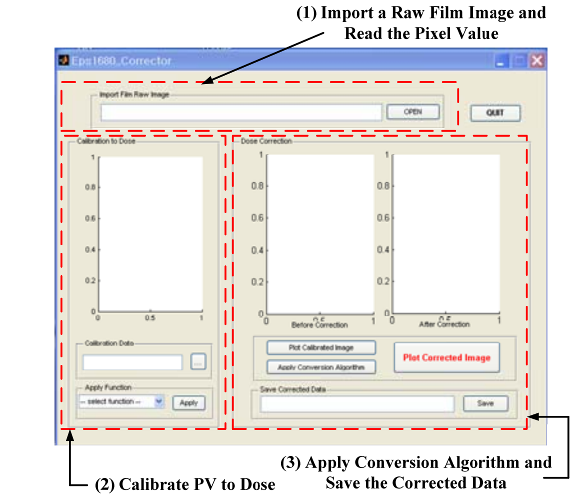

FIG. 3. A GUI-based Software Composed of Three Categories including Data Import, Calibration, and Conversion Regions Based on New Algorithm

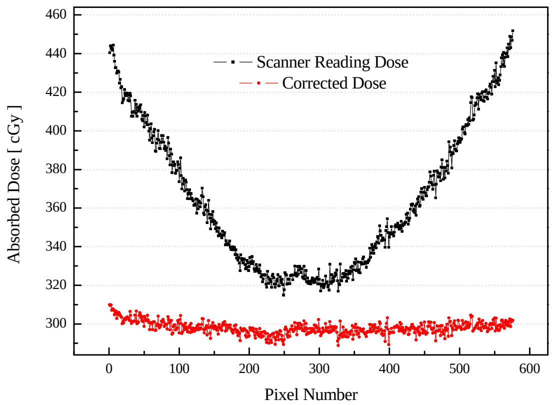

FIG. 4. A Comparison of Scanner Reading Dose and Actual Dose Corrected by Applying the Algorithm to Pixel-by-Pixel

3. Results and Discussions

The scanner-read dose values were corrected with the software and the result was compared with the original values before correction (see Fig. 4). For this experiment, the whole area of an EBT film was irradiated uniformly at the dose level of 307.1 cGy. Figure 4 shows that the difference monotonically increases in the horizontal direction, from the center to the edge-sides of the scanner, for the uncorrected values (black line). The maximum difference in the raw data was about 30% at the edge-sides, but the difference was reduced to less than 3% after applying the correction algorithm in the software developed in the present study.

4. Conclusions

The non-uniform response characteristics of a flat-bed scanner was analyzed and a new pixel-based correction algorithm was developed and incorporated in a GUI-based user-friendly software. By applying the new algorithm to a set of raw data, degree of dose distortion was reduced significantly, i.e., from ~30% to 3%.

It is also recognized that new algorithm is very reliable and reproduce dose values very accurately. The software was developed with flexibility in mind and it can be used for other different types of scanners.

ACKNOWLEDGEMENT

This work was supported by Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MEST) (No. M20706000007-08M0600-00712).

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