Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Novel dual-wavelength optical-CT imaging method for gel dosimeter readout

To cite this article: Yi Du *et al* 2019 *J. Phys.: Conf. Ser.* **1305** 012043

Novel dual-wavelength optical-CT imaging method for gel dosimeter readout

Yi Du[1,2,3], Xiangang Wang[2], Xincheng Xiang[2] and Yves, De Deene[3]
[1]Key Laboratory of Carcinogenesis and Translational Research (Ministry of Education/Beijing), Department of Radiotherapy, Peking University Cancer Hospital & Institute, 52 Fucheng Road, Beijing, 100142, China
[2]Institute of Nuclear & New Energy Technology, Tsinghua University, Beijing, 100084, China
[3]School of Engineering, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia

Email: wangxiangang@tsinghua.edu.cn

Abstract. Dual-wavelength scanning is a technique eliminating the need of phantom repositioning for optical-CT gel readout. To further diminish artifacts caused by phantom impurities, we hereby propose a novel dual-wavelength imaging method based on phantom impurity recognition and correction. In this method, impurities in motion trajectories during phantom rotation are recognized at the reference wavelength via motion-tracking as a binary mask, which is then applied to correct impurity-contaminated pixels at the data wavelength. Compared with the existent dual-wavelength imaging method, the proposed method is demonstrated to be capable of reducing impurity-induced artifacts and improving imaging SNR and CNR in the same process.

1. Introduction

With the wide application of highly conformal radiotherapy treatments featured by IMRT and VMAT, three-dimensional radiotherapy dosimetry has become a key research area where growing interest has been directed to gel dosimetry [1-4]. As a compact and cost-effective readout modality alternative to MRI [5-7] , optical-CT has been proposed to scan radiosensitive gel dosimeters. Optical density (OD) distribution quantitatively related to localized absorbed dose can be remapped by optical projections of transmitted light over 360 degrees, and then absolute dose distribution can be obtained via calibration between ΔOD and dose. In order to suppress imaging artifacts caused by phantom impurities, pre- and post-irradiation scans are often subtracted [8, 9]. However, as demonstrated in another abstract at this conference, this method is very sensitive to pre- and post-scan registration errors and prone to positive-negative pair errors. To avoid the problem of co-registration between pre- and post-irradiation scans, a dual-wavelength scanning has been proposed by De Deene in [10].

The principle behind dual-wavelength scanning is based on the property of wavelength-dependent absorption. As in [10], by scanning post-irradiation dosimeters at reference and data wavelengths (or channels) respectively, logarithmic projections can be calculated for tomographic reconstruction as:

$$Projection = -log_{10}\left(\frac{I_{data} - I_{dark}}{I_{ref} - I_{dark}}\right) \quad (1)$$

where I_{ref} and I_{data} are the measured transmitted light intensity at reference and data channels respectively and I_{dark} is the dark current of the detector.

In this abstract, we propose a novel dual-wavelength imaging method other than Equation (1), which uses the same dual-wavelength data but reduces imaging noise and artifacts by phantom impurity recognition and correction.

2. Method & Materials

2.1. Motion-Tracking based Impurity Recognition

The key physical principle of the proposed method is that at the reference wavelength radiosensitive chemicals turn almost transparent while phantom impurities such as stain particles will attenuate the traverse light independent of the wavelength. Hence when a dosimeter phantom is scanned at the reference wavelength, the phantom rotates along the central axis with opaque impurities projected onto the detector forming *footprint-like* continuous motion trajectories. Because of measurement noise and slight light attenuation by matrix material, phantom impurities are difficult to be directly segmented from background via threshold selection. However, the impurity motion trajectories can be recognized as a binary mask via motion-tracking, which can thereby be used to correct contaminated measurements at the data wavelength.

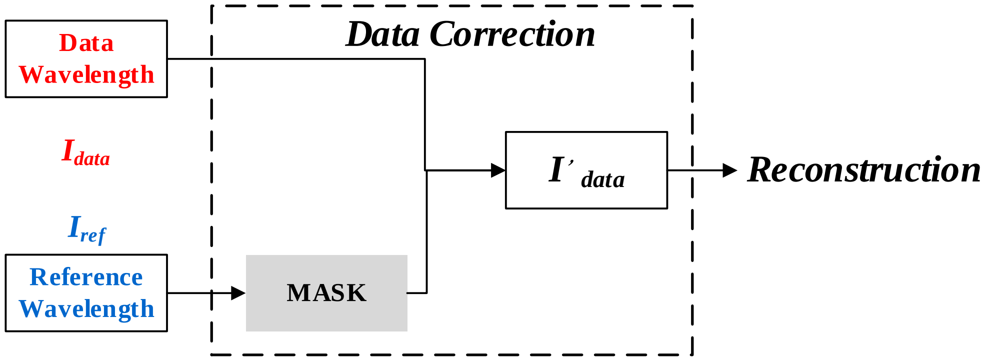


Figure 1. Key workflow of the dual-wavelength imaging method with impurity correction.

In this study, the binary mask of impurity motion trajectories is generated using a modified algorithm from the Matlab R2016a^{TM} *Motion-Based Multi-Object Tracking* example. Some parameters are tuned to improve the stability and robustness of the algorithm. When the binary mask is obtained, the corresponding pixels of the data-wavelength images, which are assumed to be contaminated by phantom impurities, are thereby eliminated and replaced by four-pixel neighborhood interpolation. The logarithmic projections are then calculated with the corrected data images and blank field image.

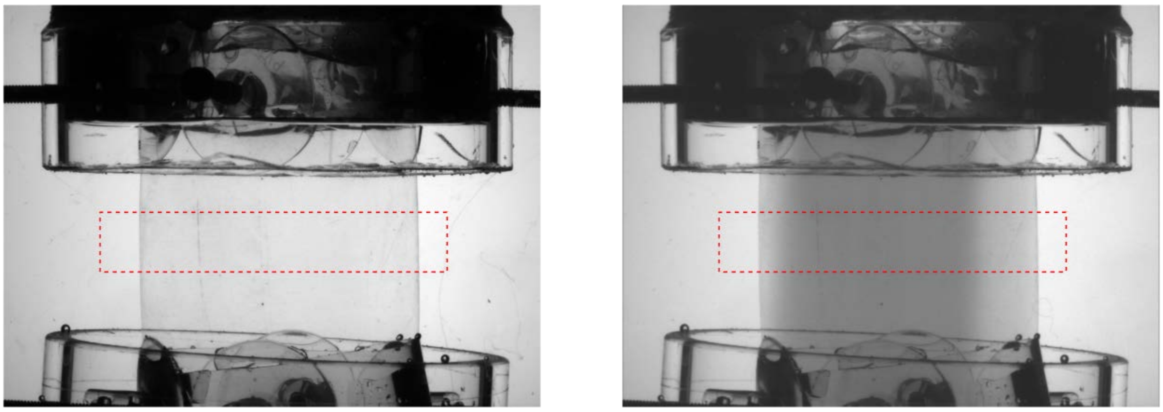
2.2. Experiment Apparatus

A cylindrical silicone dosimeter [11-13] phantom was irradiated along the central axis by a square field from a 6-MV Linac with a grid-pattern attenuator placed on top of the phantom. The attenuating grid had a divergence corresponding with the beam divergence. Posterior to irradiation, the phantom was scanned on a Vista^{TM}-rebuilt dual-wavelength optical-CT scanner with diffuse light sources at 630-nm for the data projections (red) and 530-nm for the reference projections (blue) respectively [10].

IOP Conf. Series: Journal of Physics: Conf. Series **1305** (2019) 012043 doi:10.1088/1742-6596/1305/1/012043

3. Results

3.1. Dual-wavelength Traverse Data
Figure 2 shows corresponding projections for the reference and data channels respectively.



(a) (b)

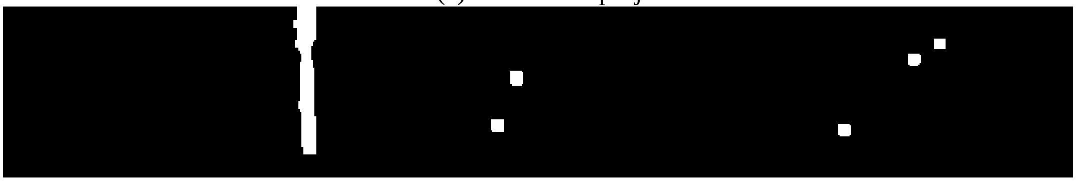
Figure 2. Reference (a) and data (b) projection scans of the silicone dosimeter (FlexyDos3D) phantom. The red box depicts the ROI for following data processing.

3.2. Impurity Recognition Mask
For illustration, Figure 3 gives one frame of the calculated impurity recognition mask together with the reference and data images at the same projection angle.

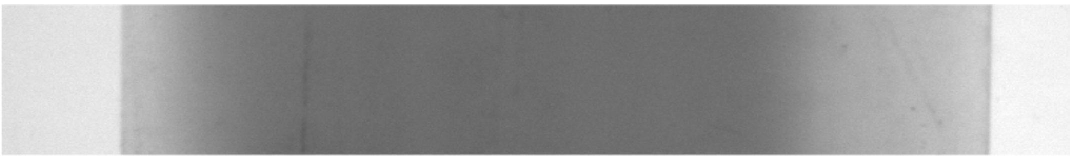
3.3. Reconstruction Image Evaluation
Three different sets of OD images are reconstructed respectively by using: (1) the data channel and its blank field data, denoted as mono-wavelength at 630 nm, (2) the dual-wavelength scan data and following the method in Equation (1), and (3) the impurities recognition and correction method proposed in this study.

Figure 4 shows the reconstructed images of the three methods. A zoomed ROI (red box) is selected, where an impurity is identified. Also, a pair of ROIs (yellow boxes) inside and outside the irradiation field are selected to calculate SNR and CNR as listed in Table 1.

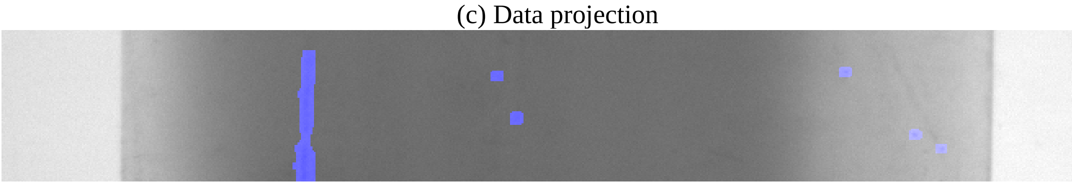
(a) Reference projection



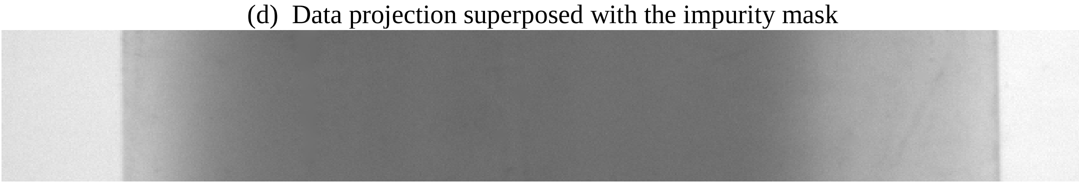
(b) Impurity mask



(c) Data projection

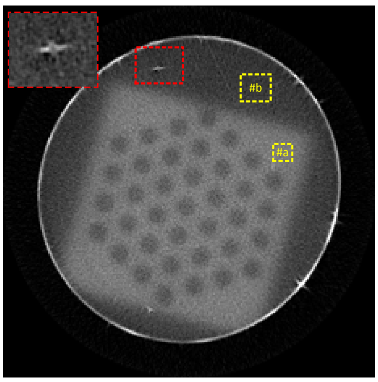


(d) Data projection superposed with the impurity mask

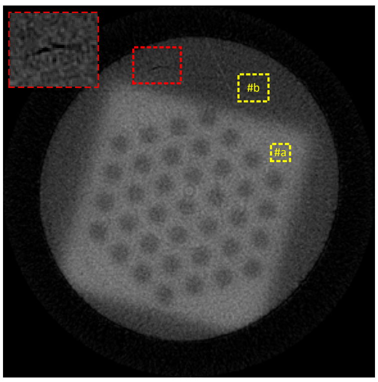


(e) Corrected data projection

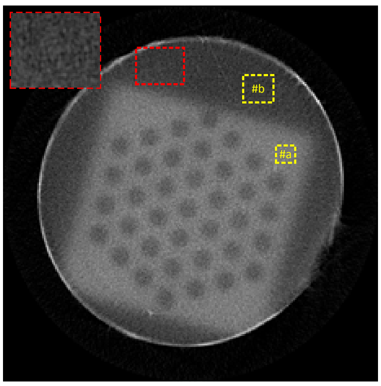
Figure 3. Illustration of the corresponding reference and data projections, recognized impurity mask and corrected data projection.



(a)



(b)



(c)

Figure 4. Reconstructed images of different methods: (a) mono-wavelength, (b) dual-wavelength via Equation (1) and (c) proposed method. The red box depicts the zoomed ROI with a dust stain visible in (a), replaced by a *negative scar* in (b), and clearly removed in (c). The yellow boxes ROI #a and ROI #b are selected to calculate the SNR and CNR.

Table 1. SNR and CNR of the images in figure 4 calculated from ROI *#a* and ROI *#b*.

Method	SNR		CNR
	ROI #a	ROI #b	
Mono-wavelength at 630 nm	10.9659	5.4264	4.3122
Dual-wavelength via Equation (1)	9.2542	4.5895	3.8368
Proposed method	11.2453	5.6022	4.4084

4. Discussion and conclusions

Similar to the conclusion in [10], dual-wavelength scanning, which eliminates the need for pre-irradiation scan, is shown effective in reducing imaging artifacts related to phantom impurities. As originality of this study, a novel dual-wavelength imaging method via impurity recognition is proposed. Based on the same data acquisition process as in [10], this method in comparison is capable of reducing impurity-induced imaging artifacts. In the meantime, improved imaging SNR and CNR is shown, which can be attributed primarily to using a smoothed light field projection for image reconstruction and partly to reducing streaking artifacts.

5. Acknowledgement

Jointly Supported by Beijing Natural Science Foundation (No. 1184014, 1174016), National Science Foundation of China (No. 61571262, 11575095), China Postdoctoral Science Foundation (No. 2017M620542) and National Key Research and Development Program (No. 2016YFC0105406).

6. References

[1] Baldock C *et al* 2010 *Phys. Med. Biol.* **55** R1-63
[2] Schreiner L J 2017 *J. Phys.: Conf. Ser.* **847** 012001
[3] Oldham M 2017 *J. Phys.: Conf. Ser.* **847** 012006
[4] Mather M L *et al* 2003 *Phys. Med. Biol.* **48** N269-75
[5] Vandecasteele J and De Deene Y 2013 *Phys. Med. Biol.* **58** 19-42
[6] Vandecasteele J and De Deene Y 2013 *Phys. Med. Biol.* **58** 43-61
[7] Vandecasteele J and De Deene Y 2013 *Phys. Med. Biol.* **58** 63-85
[8] Doran S J 2013 *J. Phys.: Conf. Ser.* **444** 012004
[9] Wuu C-S and Xu Y 2010 *J. Phys.: Conf. Ser.* **250** 012044
[10] De Deene Y 2015 *J. Phys.: Conf. Ser.* **573** 012058
[11] Høye E M *et al* 2015 *J. Phys.: Conf. Ser.* **573** 012067
[12] De Deene Y et al 2015 *Phys. Med. Biol.* **60** 1543-63
[13] Carpentier E *et al* 2016 **847** 012052