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研究課題名（和文）Toward the World's First Tumor-Following Radiation Therapy Technique: Development of High-Accuracy Tumor Tracking System

研究課題名（英文）Toward the World's First Tumor-Following Radiation Therapy Technique: Development of High-Accuracy Tumor Tracking System

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研究成果の概要（和文）：放射線治療において，治療効果を高めつつ副作用を避けるためには，病巣周辺の健康な組織への照射を極力避け，腫瘍のみへの正確な照射が要求される。とくに肺腫瘍では，照射中も呼吸などに起因してその位置，形状などが変化するため，その変化をリアルタイムに把握可能なX線透視による画像計測が期待されている。本研究では，輝度値を基本とする一般的手法よりも雑音に対して頑強なアルゴリズムを提案し，高精度と高速な腫瘍位置・輪郭の追跡手法を開発した。臨床データを用いた性能検証により，提案法は従来法よりも正確かつ高速な画像計測が可能であることを実証した。

研究成果の概要（英文）：The purpose of this research is to develop a radiographic image tracking system to track respiration-induced tumor motion in real-time for adaptive tumor following radiation therapy. The tracking system will be able to provide conformable tumor motion information and allows the treatment device to accurately deliver high-dose conformable radiation to the moving target during the treatment.
In this research project, a kernel-based algorithm and a level set method-based method have been developed for tracking the tumor’s position and its boundary in kilo-voltage (kV) images and megavoltage (MV) images. The experimental results performed on the phantom and clinical data sets demonstrated the effectiveness of the systems for clinical application.

研究分野：医用画像処理

キーワード：画像誘導放射線治療　マーカレス追尾　MVX線画像

１．研究開始当初の背景

(1) Radiation therapy has been one of the most effective modalities for cancer treatment. About half of all cancer patients receive radiation therapy during the course of treatment. In a number of common cancers, such as lung cancer, however, the respiration-induced tumor motion significantly degrades the efficiency of radiation delivery and brings risk to the healthy tissues around the tumor. Over the past decade, extensive efforts have been devoted to solve this problem. Among various solutions, tracking tumor in real-time plays an important role.

(2) Conventional tracking systems utilize external or implanted markers as the surrogate of tumor motion. A common disadvantage, however, is that the tracking results are inaccurate since the motions of the external and implanted markers are uncorrelated with the tumor motion frequently. In addition, due to the non-continuous irradiation, the treatment process is ineffective and time-consuming.

２．研究の目的

The objective of this research is to develop a non-invasive tumor tracking system for IGRT. Specifically, we attempt to (1) utilize a kV (measurement beam) and a mega-voltage (MV) X-ray (treatment beam) imaging systems to acquire two X-ray image sequences for monitoring the tumor motion in real-time during radiation delivery; (2) develop a high-accuracy real-time tumor tracking algorithm that will be able to track not only the tumor's position, but also the tumor's boundary changing with the respiration; and (3) conduct sufficient experiments on phantom and clinical images to evaluate the reliability of our proposed tracking system.

３．研究の方法

As shown in Fig 1, the following four tasks has been done during the past 2 fiscal years.

(1) Phantom and clinical data acquisitions and analysis (Fig 1 (1)). In order to evaluate the performance of the tumor tracking algorithm, phantom and clinical radiographic image data were acquired and collected at the Tohoku university hospital and Hirosaki university hospital. On the bases of the current treatment environment, the four-dimensional computed tomography (4-D CT), kilo-voltage (kV), and megavoltage (MV) X-ray image sequences were acquired in the radiation therapy treatment. In addition, a 3-D printer-based phantom experiment was conducted for

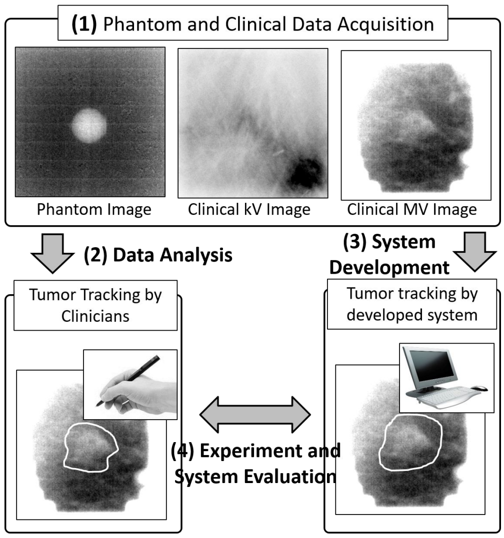

Fig 1. An overview of the research method and materials.

simulation of tumor motion.

(2) Clinical data analysis (Fig 1 (2)). A graphical user interface (GUI) was developed for analyzing the tumor motion in clinical data. The tumor motion and its boundary in the kV and MV X-ray images were drawn manually by multiple clinicians. As the ground truth, the result obtained from the clinicians was used for evaluation of tumor tracking accuracy.

(3) Tracking system development (Fig 1 (3)). A kernel-based tracking algorithm and a level set method-based tracking algorithm were developed using MATLAB to track the tumor’s position and it boundary in kV and MV X-ray image sequences.

(4) Experiments and system evaluation (Fig 1 (4)). We conducted the tumor tracking experiments on the phantom, clinical kV and MV image date sets. The tracking results were compared with the clinicians’ analysis results. For tumor position tracking, the mean and standard deviation of the tracking error were used as the evaluation indexes. For the tumor boundary tracking, an overlap index (OI) was used as the evaluation index. In addition, several previous tracking algorithms based on template matching were implemented, and the tracking performances were evaluated in comparison with the previous tracking methods.

４．研究成果

In this research, the following five achievements have been made during the past 2 fiscal years.

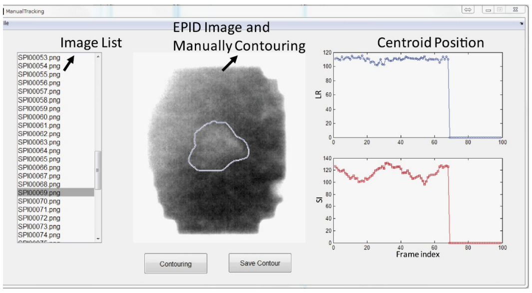

Fig 2. A GUI application for analyzing the tumor motion in clinical data.

(1) Phantom and clinical data acquisitions. During the past 2 fiscal years, a set of phantom and over 20 clinical radiographic image data, including 4D-CT, kilo-voltage (kV), and megavoltage (MV), for lung cancer treatment have been acquired and collected at the Tohoku university hospital and Hirosaki university hospital. The usage of clinical data has been approved by the Committee of Medical Ethics of Hirosaki University Graduate School of Medicine. Fig. 1 (1) shows three examples of the phantom, clinical kV image, and clinical MV images.

(2) Clinical data analysis. A graphical user interface (GUI) has been developed using MATLAB for analyzing the tumor motion in clinical data. The tumor motion and its boundary can be drawn manually by clinicians as the ground truths for tracking system evaluation. Fig 2 shows the developed GUI application in which tumor boundary in an MV image sequence can be manually drawn by the clinicians and its isocenter can be automatically recorded.

(3) Development of tumor tracking system. During the past 2 fiscal years, we have developed a kernel-based tracking algorithm and a level set method-based tracking algorithm using MATLAB to track the tumor's position and it boundary in kV and MV X-ray image sequences. The developed tracking system, which utilized advanced digital image processing and visual tracking techniques, have been tested and evaluated using a set of phantom and clinical image date. In addition, several previous tracking methods have been implemented on the MATLAB. The previous methods have also been tested and evaluated using the phantom and clinical image data. For improving the computational speed, we have also improved the implementation of the tracking algorithm based on a GPU computation platform.

(4) Tumor position tracking experiments and its evaluation. We have conducted a set of experiments to evaluate the kernel-based tracking method by using clinical kV X-ray image. Fig. 3 shows two experiments and the tumors positions obtained from the tracking system and the ground truths generated by clinicians. As shown in Fig. 4, the experimental results conducted on five clinical kV image sequences demonstrated that the tracking accuracy of the proposed method is superior to the conventional template matching methods. In addition, our proposed method has a lower computational cost compared with previous template matching- based methods, and shows a promising perspective for real-time tumor tracking in clinical application.

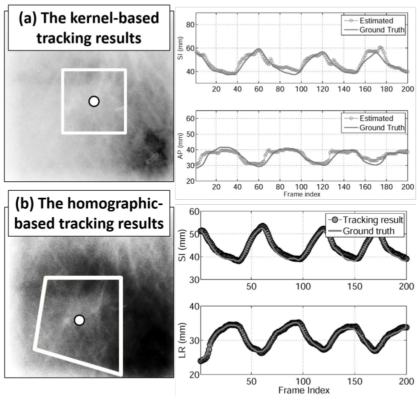

Fig 3. Experimental results for tracking tumor position in kV images.

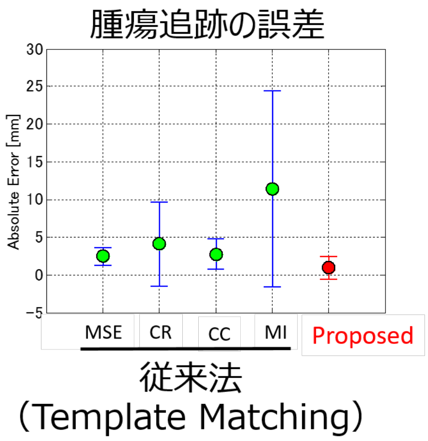

Fig 4. A comparison of tracking accuracy between the proposed method and four previous template matching-based methods.

(5) Tumor boundary tracking experiments and its evaluation. For the tumor boundary tracking system, we have also conducted a set of experiments on phantom and clinical MV X-ray images to evaluate its accuracy. Fig. 5 shows an MV X-ray images and the tumors boundary obtained from the tracking system.

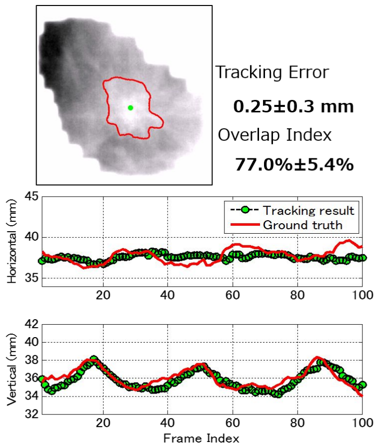

Fig 5. An experimental result of tracking tumor boundary in MV images

As shown in Fig. 5, the experimental results demonstrated that the tracking results have a good agreement with the ground truths, and it shows a perspective for real-time tumor-following radiation therapy.

5．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計 2 件）

① <u>Xiaoyong Zhang</u>,et al.,“Tracking Tumor Boundary in MV-EPID Images Without Implanted Markers: A Feasibility Study”, Medical Physics, 査読有, Vol. 42, No. 2, 2015, pp. 2510-2513,DOI: 10.1118/1.4918578

② <u>Xiaoyong Zhang</u>,et al.,“Is Mammographic Breast Density a Risk Factor for Breast Cancer in Japanese Women”, Bulletin of School of Health Sciences Tohoku University, 査読有, Vol. 24,2015, pp. 45-51

〔学会発表〕（計 16 件）

① <u>Xiaoyong Zhang</u>,et al.,“A Real-Time homography-Based Tracking Method for Tracking Tumor Motion in Fluoroscopy”, SICE Annual Conference, 2016 年 9 月 23 日,「つくば国際会議場（茨城県・つくば市）」

② Shintaro Suzuki, <u>Xiaoyong Zhang</u>,et al.,“Detection of Mass on Mammograms Using Deep Convolutional Neural Network: A Feasibility Study”, 58th American Association of Physicists in Medicine Annual Meeting (AAPM2016), 2016 年 8 月 3 日,「Washington, DC (USA)」

③ <u>Xiaoyong Zhang</u>,et al.,“Tumor Motion Tracking Using kV/MV X-Ray Fluoroscopy for Adaptive Radiation Therapy”, 2015 International Workshop on Computational Intelligence for Multimedia Understanding, 2015 年 10 月 30 日,「Prague(Czech Republic)」

④ <u>Xiaoyong Zhang</u>,et al.,“A Real-Time Homography-Based Algorithm for Markerless Deformable Lung Tumor Motion Tracking Using kV X-Ray Fluoroscopy”, 57th American Association of Physicists in Medicine Annual Meeting (AAPM2015), 2015 年 7 月 15 日,「Anaheim (USA)」

〔図書〕（計 0 件）

〔産業財産権〕

○出願状況（計 0 件）

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発明者：
権利者：
種類：
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国内外の別：

〔その他〕
ホームページ等

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