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研究課題名（和文）2D-3D Reconstruction for internal organs using Deep Learning Techniques

研究課題名（英文）2D-3D Reconstruction for internal organs using Deep Learning Techniques

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研究成果の概要（和文）：本研究では、高精度に二次元から三次元を再構築する技術の開発を目指している。三次元の構築精度を向上させるため、学習モデルに基づく方法とSparse-Viewに基づく方法の二つの方向で研究を行った。既存の学習モデルX2CTGANの弱点を分析し、新たな投影制限および回転トランスフォーマーを追加することで、構築性能を向上させた（SSIMスコアを0.6ぐらいから0.8まで向上された）。これらの成果をまとめて国際会議に投稿する。一方、SparseからDenseへ、最終的に三次元を構築する手法も研究し、CT画像のZ方向での構築に成功した。その成果は既にジャーナルペーパーとして発表している。

研究成果の学術的意義や社会的意義
本研究では、二次元から三次元を再構築する手法を提案した。この手法は、さまざまな場面で活用できると考えられる。例えば、X線画像からCTの再構築、シングルビューからマルチビューの再構築、RGB画像から三次元動作の再構築などに役立つ。さらに、提案したデータ拡張手法により、学習データが不足していても、効果的に学習ができ、汎化性能も向上するようになった。こうしたデータ拡張の手法は、他の研究テーマでも適用可能である。本研究では、基礎技術の研究開発が進み、さまざまなアプリケーションにも適用できると考えられ、それによって大きな社会的な意義があると考えられる。

研究成果の概要（英文）：In this study, we aim to develop a high-precision technique for reconstructing three-dimensional structures from two-dimensional images. To improve the accuracy of three-dimensional reconstruction, we conducted researches in two directions: deep-learning-based methods and methods based on Sparse-View. We analyzed the weaknesses of an existing learning model X2CTGAN and improved the reconstruction performance by adding new projection constraints and a rotational transformation, resulting in an increase in the SSIM score from approximately 0.6 to 0.8. We will summary these results and submit them to an international conference.
Meanwhile, we also researched methods to reconstruct three-dimensional structures from Sparse to Dense views, and successfully reconstructed in the Z-direction of CT images. The results have already been published as a journal paper.

研究分野：Computer Vision

キーワード：3D reconstruction　machine learning　X-ray　CT　deformation estimation

１．研究開始当初の背景

2D-3D reconstruction has been widely used in automatic diagnosis, surgery navigation, and radiotherapy planning for decades. In traditional methods, intraoperative 3D model was always computed by deforming the preoperative 3D model [1]. However, large deformation and motion of organs often occur during the surgery, making the conventional deformation models difficult to predict the intraoperative 3D model precisely. On the other hand, vision-based 3D reconstruction that uses many 2D images captured from multiple viewpoints, is nearly impossible in medical field because of the limitations of surgeries.

Recently, as the rapid development of deep learning techniques, reconstructing 3D from fewer 2D images, even single image, becomes possible. This throws light on 3D reconstruction for medical uses. In theory, high accuracy can be obtained if only the training data are sufficient. Nevertheless, collecting a great amount of 2D-3D data for training is nearly impossible in medical field. Therefore, how to build a learning model which can realize correct 2D-3D reconstruction from a small size of database is a key issue in this research topic.

[1] M. Nakao, "Simulating Lung Tumor Motion for Dynamic Tumor-Tracking Irradiation", IEEE NSS/MIC, 2007.

２．研究の目的

The objectives of this study are to achieve (a) a precise not just approximate 3D volume model from its corresponded 2D image, and (b) a solution for training data insufficiency in medical field.

３．研究の方法

3.1 Database and Data Augmentation

Our research is based on a publicly available LIDC-IDRI dataset [2], which consists of 3D CT images. To increase the number and also diversity of the training data, we applied rotational transformations at 1° intervals on OY and OZ plane views of CT volume, with rotation angles constrained in [-5°, 5°]. This process generated 121 rotated CT samples for each original CT scan. With the augmentation skill, we can train the machine learning model even with a small size database. In our research, we selected CT scan from 102 subjects from the LIDC-IDRI dataset because these CT scans are less noisy. Among the selected CT data, 90 scans are allocated for training and the other 12 scans are for testing.

3.2 Proposed 2D-3D Reconstruction Approaches

In this research, we pursued our objectives from two different directions. The first one is learning-based-method, starting from a pretrained model call X2CTGAN [3], which reconstructs 3D CT scans from biplanar 2D X-ray images. It achieved a performance score of 0.62 in terms of SSIM (structural similarity index measure). In this previous work, both the reconstruction loss and vertical projection loss rely entirely on the ground truth, and the biplanar 2D X-rays are commonly treated merely as raw inputs for feature extraction and dimension transformation. These makes CT images focusing only on general shape consistency and lacking interpretability of deep correlations between input and output images. Moreover, correct 3D volume is difficult to be reconstructed due to the lack of information of the input images. To solve these problems, as shown in Fig.1, we simulated small positional offsets that subjects may have during X-ray image acquisition and designed a rotational transformation sampling grid during the data learning process. Meanwhile, we incorporated perspective projection

constraints into the process of reconstructing CT. This integration establishes a clearer relationship between the input and output, maintaining their consistency. Moreover, we investigated how many views of X-ray images is enough to reconstruct qualified CT scans; and also improved the reconstruction performance by leveraging the rotation priors and new projection constraints. These works were summarized recently, and we planned to submit them to international conferences.

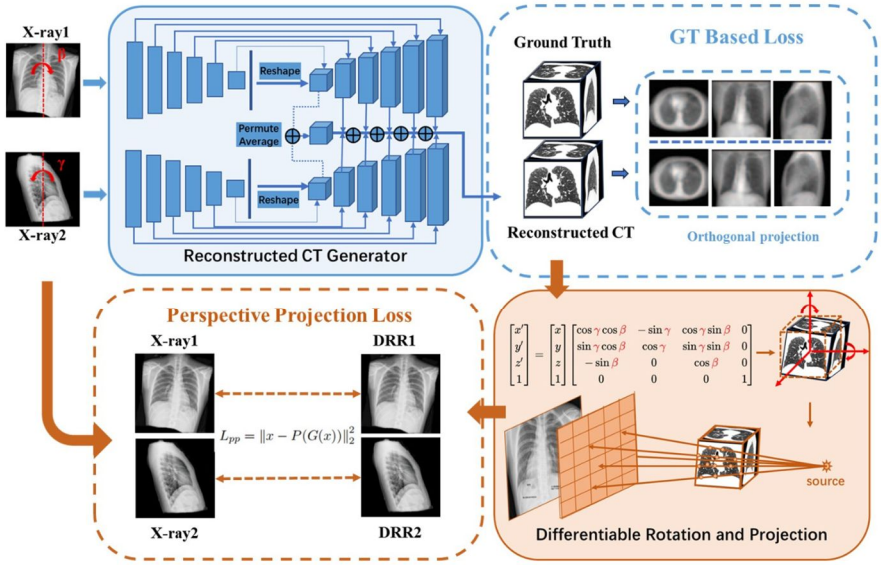

Fig. 1. The overview of our proposed approach.

The second direction is sparse-to-dense-view reconstruction. The basic idea is to create middle views from two adjacent views, and finally fulfill the fully 3D reconstruction. This idea has been proved in the application of reconstruction in the longitudinal direction of CT scans. This work has been already summarized and published in a journal.

[2] Armato III, S.G., McLennan, G., Bidaut, L., McNitt-Gray, M.F., Meyer, C.R., Reeves, A.P., Zhao, B., Aberle, D.R., Henschke, C.I., Hoffman, E.A., et al.: The lung image database consortium (lidc) and image database resource initiative (idri): a completed reference database of lung nodules on ct scans. Medical physics 38(2), 915–931 (2011).
[3] Ying, X., Guo, H., Ma, K., Wu, J., Weng, Z., Zheng, Y.: X2ct-gan: reconstructing ct from biplanar x-rays with generative adversarial networks. In: Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. pp. 10619– 10628 (2019).

４．研究成果

We improved a pretrained model X2CTGAN to realize the correct 2D-3D reconstruction by exploiting new perspective projection constraints and rotational transformation. These works will be submitted to international conferences.
We also researched the sparse-to-dense 3D reconstruction; and applied it to an application which reconstructed the information in the longitudinal direction of CT scans. This work has been published as a journal paper.

[1] S. Wu (代表者), M. Nakao, K. Imanishi, M. Nakamura, T. Mizowaki, T. Matsuda, “Computed Tomography slice interpolation in the longitudinal direction based on deep learning techniques: To reduce slice thickness or slice increment without dose increase,” PLoS ONE, Vol. 17, No. 12, pp. 1-18, Dec. 2022.
[2] S. Wu (代表者), “Facilitating computed-tomography-based diagnosis using deep learning techniques,” The 25th SANKEN International Symposium, online, p. Y1-4, Jan. 2022.

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　1件）

１．著者名 Wu Shuqiong、Nakao Megumi、Imanishi Keiho、Nakamura Mitsuhiro、Mizowaki Takashi、Matsuda Tetsuya	４．巻 17
２．論文標題 Computed Tomography slice interpolation in the longitudinal direction based on deep learning techniques: To reduce slice thickness or slice increment without dose increase	５．発行年 2022年
３．雑誌名 PLOS ONE	６．最初と最後の頁 1～18
掲載論文のDOI（デジタルオブジェクト識別子） 10.1371/journal.pone.0279005	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計2件（うち招待講演　1件／うち国際学会　0件）

１．発表者名 Shuqiong Wu
２．発表標題 Facilitating computed-tomography-based diagnosis using deep learning techniques
３．学会等名 The 25th SANKEN International Symposium
４．発表年 2022年

１．発表者名 Shuqiong Wu
２．発表標題 Super-resolution and from-2D-to-3D CT image reconstruction based on machine learning techniques
３．学会等名 第60回日本生体医工学会大会（招待講演）
４．発表年 2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関