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学 位 論 文 題 目	Three-Dimensional Image Processing for Artifact Reduction and Quality Improvement in Medical X-ray Computed Tomography (医療用X線CT画像におけるアーチファクト除去および画質向上のための3次元画像処理)
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学位論文内容の要旨

When metallic prosthetic appliances and dental fillings exist in the oral cavity, the appearance of metal-induced streak artifacts is not avoidable in computed tomography (CT) images. The general objective of this research work was to reduce the metal-induced streak artifacts using successive iterative reconstruction method. Maximum likelihood-expectation maximization (ML-EM) and ordered subset-expectation maximization (OS-EM) algorithms were analyzed and used in this study. Besides streak artifact reduction, 3D filtering method and region growing method were applied to improve image quality.

In Chapter I, discipline of medical imaging was introduced. Among several medical imaging modalities, X-ray computed tomography was emphatically introduced from its tomography principles to its application. Artifacts which were usually observed on CT images were analyzed and sorted to several kinds. Although the traditional CT reconstruction method, the filtered back-projection algorithm, had been widely applied, it could not deal with the loss of portions on projection data which was caused by extremely high X-ray absorption coefficients of metallic biomaterials. Image reconstruction algorithms that can use the corrupted projection data were expected.

In Chapter II, regularly used image format, DICOM, was introduced. It is the abbreviation of digital imaging and communication in medicine. Next, two medical image displaying software, Image J (Ver.1.421, NIH) and OsiriX (Ver.4.1.2, OsiriX Fundation, Geneva, Switzerland), were introduced. We used Image J to display and analyze 2D images. We used OsiriX to present 3D volume rendering.

In Chapter III, projection data acquisition on X-ray CT modality was instructed in detail. All the projection data were acquired in 360 directions with 1° intervals in this study. Then, iterative restoration methods as CT image reconstruction algorithms, ML-EM and OS-EM, were proposed. The two algorithms both result in an approximation between the processing image and the target image.

Convergence validation of both ML-EM and OS-EM algorithm was carried out on practical images. It can be concluded that almost 300 iterations were needed to reconstruct the practical image by ML-EM, while the iteration times was about 50 for OS-EM algorithm to reconstruct the same image. The OS-EM algorithm can reconstruct image data faster without image quality dropped and it is usually used to reduce calculation time.

In Chapter IV, optimal iteration of ML-EM algorithm was tested when using in streak artifact reduction. 50 iterations could reach a best artifact reduction effect. We applied the ML-EM on a sequential CT images to reduce artifacts using the same artifact-free image's projection data. For OS-EM algorithm, the best parameter combination was proved to be subset = 8 and iteration = 10.

In Chapter V, we proposed the successive iterative reconstruction method (SIRM) based on the fact that adjacent CT images often depict very similar anatomical structures on sequential thin-slice images. We used SIRM for streak artifact reduction in dento-alveolar region. First the projection data of the artifact-free slice was obtained. The adjacent slice, which showed weak artifacts, was processed using the artifact-free slice's projection data. Then the projection data of the newly processed image was obtained and it was used to reconstruct the next image which contained a little more artifacts. In this manner, the processing continued until the heave streak artifact containing image was processed. Two algorithms were tested in processing sequential images for artifact reduction with SIRM.

In Chapter VI, SIRM was clinically applied in streak artifact reduction. Images before and after sagittal split ramus osteotomy operation (a jaw deformity case) were processed. The method was also proved to be effective in reducing artifacts caused by orthodontic wire, brackets, bone screws or titanium plates. Calculation acceleration was realized by general purpose graphic processing unit (GPGPU).

In Chapter VII, SIRM was applied in cone-beam CT images for streak artifact reduction. Besides, 3D filtering method and region growing method with dilation and erosion were employed for image quality improvement.

論文審査結果の要旨

近年、医療用X線CTにおける統計的画像再構成法の応用に関する研究が盛んに行われている。しかし、その多くは計算負荷を多くしながらも画質改善と患者への被曝軽減の実現を目的としており、金属アーチファクト軽減やコーンビーム型CT装置への応用は未開発の分野で、今後の発展が待たれている状況である。

本論文は、このような状況にある統計的画像再構成法の応用について、隣接する画像のプロジェクション・データを逐次近似法で処理して、金属アーチファクトの軽減や画質の向上に関して研究し、臨床応用可能な画像処理法を開発することを目的としたものである。提案されている手法の特徴は以下のとおりである。

- 医科用のMDCT画像を用いて、ML-EM法でアーチファクト軽減を実証し、successive iterationと名付けた方法で解剖学構造の再現性を向上させた。さらに、計算負荷の削減のためにOS-EM法を応用した。また、GPGPUマシンで計算の高速化を実証した。
- 歯科用のコーンビームCT画像にも同じアルゴリズムを応用してアーチファクトの軽減を図り、3次元フィルタリングや領域拡張法による画質の向上を示した。

これを要するに、申請者は、医療用X線CTの金属アーチファクトの削減と画質の向上に新知見を得たものであり、医用画像工学分野に対して貢献するところ大なるものがある。

よって、申請者は、北見工業大学博士（工学）の学位を授与される資格があるものと認める。