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# 論　文　内　容　の　要　旨

氏　名　　FAIROZA AMIRA BINTI HAMZAH

The four-dimensional (4D) images such as 4D magnetic resonance image (MRI), 4D computed tomography (CT) and other types of 4D medical images have high slice resolution up to 1024×1024 or more at increasing pixel bit-depth. The limitations in storage space and transmission bandwidth has triggered a huge investigation on multidimensional and dynamic image compression to efficiently store and transmit the 4D images.

Since few decades ago, Discrete Cosine Transform (DCT) based digital image signal compression had been adopted as the JPEG international standard. Later, Discrete Wavelet Transform (DWT) has replaced the DCT and its being applied in medical image compression. JPEG 2000, the international standardization of DWT is using separable lifting structure where the multidimensional image signal is transformed separately in its horizontal and vertical direction. Besides that, each process is realized by cascading in lifting calculation. However, the necessity of waiting for previous step before calculating to the next step will make the overall delay time become longer. The delay time between input and output of WT is reduced as the proposed method reduces its lifting steps. Since the lifting step contains a rounding operation, variance of the rounding noise generated due to the rounding operation inside the transform is reduced.

Unlike the conventional separable structure, the proposed non-separable structure reduces the rounding noise inside the transform, which will lead to the increasing of coding performance. The proposed wavelet transform has a merit that its output signal, apart from the rounding noise, is the same as the conventional separable structure which is a cascade of 1D structure. As a result of experiments in the first proposal, it was observed that the proposed

method reduces the rounding noise as well as increases the performance of data compression of various 4D input signals.

The JPEG 2000 restricts the user's choice to two wavelet transforms—Daubechies 9/7 for lossy compression and the 5/3 LeGall wavelet, which has rational coefficients for reversible or lossless compression. The non-separable 3D and 4D structure in the 5/3-type transform for lossless coding reduces rounding noise, but it increases in the 9/7-type transform for lossy coding in the structure. A combination of 2D and 3D non-separable structures for 4D integer WT has been proposed to solve this problem, but it is found that the original filter arrangements need to be preserved to reduce rounding noise.

Therefore, in the second proposal, a non-separable 2D structure for the integer implementation of a 4D quadruple lifting WT with a 9/7 filter is proposed. The proposed wavelet transform has the same output signal as the conventional separable structure except for the rounding noise. As the order of the original lifting scheme is preserved, rounding noise in pixels of the decoded image can be significantly reduced, and the upper bounds of quality and lossy decoded 4D medical images can be improved.

Furthermore, the proposed methods can be extended in various ways to increase the coding performance for such multidimensional images, such as by implementing the region-of-interest (ROI) coding to utilize both lossless and lossy coding efficiently. Thus, an ROI coding is introduced in the third proposal for the non-separable lifting structure of 4D integer WT to compress the images by preserving the important part of the image only. It was observed that the proposed method increased the coding performance for 4D images.

Moreover, to further improve the performance of lossless coding, the adaptive directional lifting structure is introduced in the fourth proposal. This structure uses different lifting directions and optimally applies to the non-separable three-dimensional (3D) integer WT according to their own property. The adaptive structure has the advantage over the

non-adaptive by further compacting the energy of low-frequency band signals and thus will increase its coding performance. It is proved that the proposed method in this proposal increase the lossless coding performance of various signals such as the video, medical image and light field image.