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Efficient CT X-Ray Dose Utilization and Efficient Computation with a Logarithmic Data Transformation, a Gain Matrix, Iterations with Near Orthogonal Object Density Updates, and Progressive Resolution

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BACKGROUND

Body cross-sectional tomographic reconstructions require near single to multi-sievert CT scanning. To achieve the goal of reducing radiation exposure, a new statistically efficient non-linear (additional logarithmic transformation applied to the equivalent marginal (!) probability densities) reconstruction algorithm combines the transformed projection-data by forming orthogonal innovations from projections for the efficient x-ray object density estimation. The algorithm allows for: (i) a several-fold reduction of the required projection count resulting from the efficient use of the transformed marginal probability densities; and (ii) rapid convergence of the object density estimate resulting from orthogonal data transformations in conjunction with a Kalman gain matrix G, adapted through recursions. Reconstruction is further accelerated by recursive, nested, multiscalar processing.

EVALUATION

Generalizing the usefulness of a logarithmic transformation of two independent marginal probabilities, the speed of the new method becomes comparable to linear methods. Typically, it requires only a few, if any, high-resolution iterations. Efficiency of extracting structural information is assessed through residual analysis. This analysis shows quantum noise dominating faint, if any, object features. The method has been applied to transmission electron microscopy (TEM), diffusion tensor MRI (DTI), and X-ray phantom angiography. Consistently, the signal-to-noise ratio was significantly improved when compared to other non-linear iterative methods and/or the number of projections could be reduced many-fold for further acceleration.

DISCUSSION

The new method is flexible and accurate, as it extracts all information (white residuals) and leads to numerical efficiency. When compared to untransformed projection-data based methods, the positively constrained solution and ability for many-fold reduction in projection count allows for significant reduction in CT x-ray dose. The same efficiency applies to compressed sensing in MRI imaging.

CONCLUSION

Sub-millisievert CT scanning, accelerated computation and improved accuracy are the leading objectives to improve CT utility. Fast reconstruction with efficient information extraction, as shown here, has great potential to reduce patient dose, provide real time image processing, and deliver high image fidelity.

PATENTS

US: 8,660,328, 8,660,330; PCT: EP2310840, EP2593906; CN: ZL 200980123522.8; JP: 5543448;

Schematic of Kalman Filter Structure Applied to Noisy Iterative CT Reconstruction

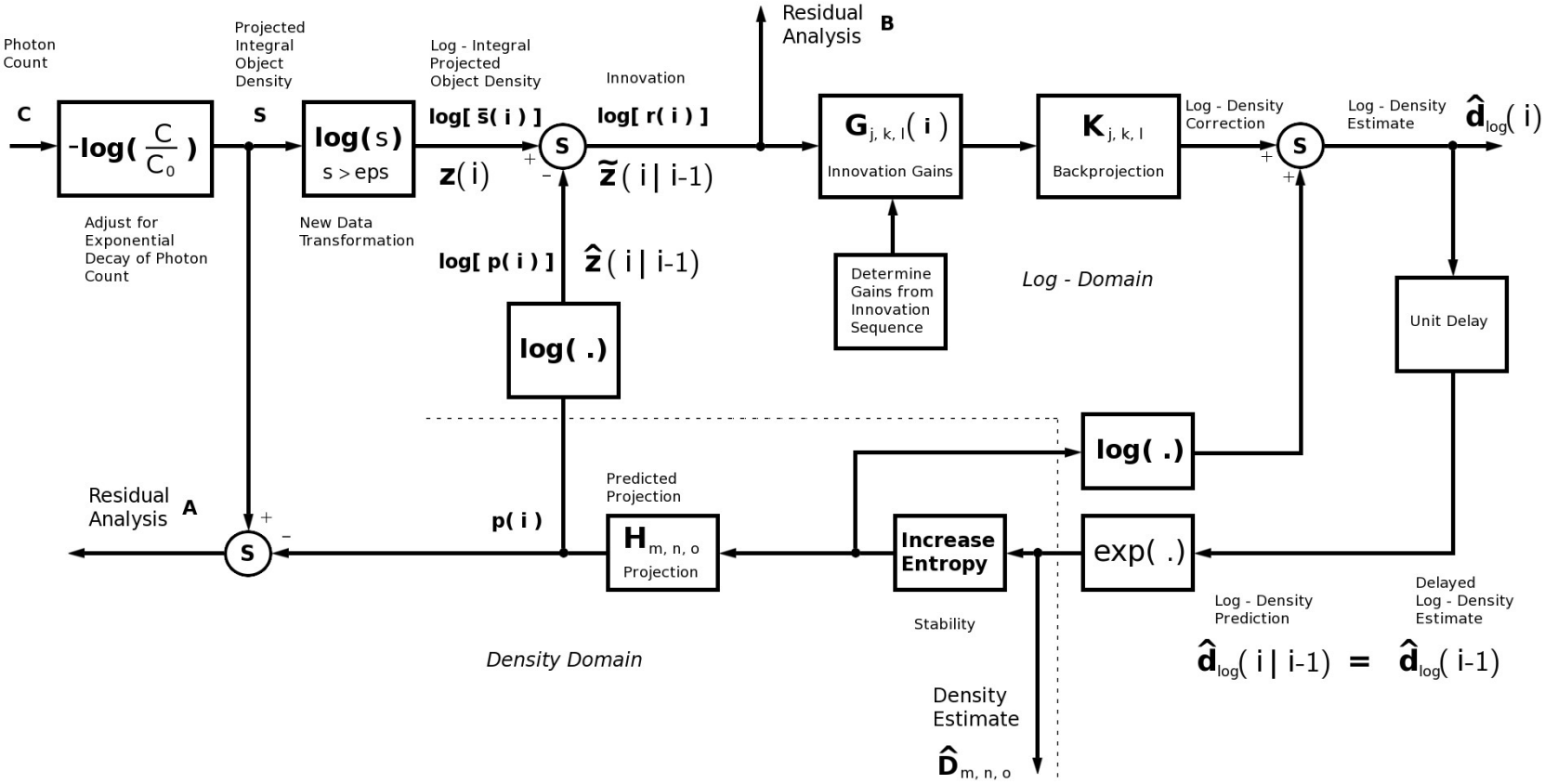

Figure 1 : Detailed information flow in HECTOR. The estimation of the innovation gain **G** cannot be pursued with the Kalman filter equations due to the size of the matrices involved. Considering the orthogonality of the components of the innovation process, however, the gain matrix **G** must be near diagonal. These diagonal elements g of **G** are then estimated from criteria of the randomness of the innovation process in the sequence of iterations. This approach leads to rapid convergence of the density estimate **D**.