Effective sparse representation of X-Ray medical images

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***Abstract*— Effective sparse representation of X-Ray medical images within the context of data reduction is considered. The proposed framework is shown to render an enormous reduction in the cardinality of the data set required to represent this class of images at very good quality. The particularity of the approach is that it can be implemented at very competitive processing time and low memory requirements.**

I. Introduction

Within the field of medical imaging for diagnosis, radiology generates huge volumes of data in the form of X-Ray images. Complying with archive provisions legislation, which may require to store the patient's data for up to ten years, represents a demanding burden for hospitals and individual radiology practices. Additionally, the prompt distribution of remote radiology reporting is one of the challenges in teleradiology. These matters have led several radiological societies to recommend to use irreversible (or 'lossy') compression "in a manner that is visually imperceptible and/or without loss of diagnostic performance" [1].

At least for extensive use, the state of the art for lossy image compression are the JPEG and JPEG2000 standards. Both techniques belong to the category of transformation coding, because are based on a compression scheme that applies an invertible transformation as the first step in the process. JPEG uses the Discrete Cosine Transform (DCT) for that purpose and JPEG2000 the Discrete Wavelet Transform (DWT). Both transformations play the role of reducing the non-negligible points in the transformed domain. The transformation we adopt here for the same purpose is different in essence. Rather than transforming the data into an array of the same dimensionality to disregard some points there, we expand the representation domain and strive to achieve a highly sparse representation in the extended domain.

Apart from the perceived advantage of sparse representations for medical image processing and health informatics [2], the emerging theory of compressive sensing has introduced a strong reason to achieve sparsity. Within the compressive sensing structure the number of measurements needed for accurate representation of a signal informational content decreases if the sparsity of the representation improves [3]–[5].

This Communication presents a framework rendering high sparsity in the representation of X-Ray medical images. This is achieved by:

(a) Creating a large redundant 'dictionary' of suitable elements for the image decomposition.
(b) Applying effective strategies for selecting the particular elements which enable the sparse decomposition of a given image.

The goal is to achieve high sparsity, with high quality reconstruction, at competitive processing time. Comparison of the results arising from the proposed framework with those yielded by the traditional DCT or DWT approximations demonstrates a massive improvement in sparsity.

II. Sparse Image Representation

Let's start by introducing some notational convention: bold face lower and upper cases are used to represent one dimension (1D) and two dimension (2D) arrays, respectively. Standard mathematical fonts indicate component, e.g., $\mathbf{c} \in \mathbb{R}^K$ is an array of real components, $c(k)$, $k = 1, \ldots, K$, and $\mathbf{I} \in \mathbb{R}^{N_x \times N_y}$ an array of real elements, $I(i,j)$, $i = 1, \ldots, N_x$, $i = 1, \ldots, N_y$.

Restricting considerations to l-bit gray scale images, an image is represented by an array $\mathbf{I} \in \mathbb{R}^{N_x \times N_y}$ the elements of which, called intensity pixels, are given by integer numbers from 0 to 2^l-1.

Within the adopted framework for representations using dictionaries an image $\mathbf{I} \in \mathbb{R}^{N_x \times N_y}$ is approximated by a linear decomposition of the form:

$$\mathbf{I}^K = \sum_{k=1}^{K} c(k) \mathbf{D}_{\ell_k}, \tag{1}$$

where each $\mathbf{D}_{\ell_k}$ is an element of $\mathbb{R}^{N_x \times N_y}$ normalized to unity, called 'atom'. The K-atoms in (1) are selected from a redundant set called a dictionary. A *sparse approximation* of $\mathbf{I}$ is an approximation of the form (1) such that the number of K-terms in the decomposition is significantly smaller than $N = N_x N_y$.