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Lossless Image Compression through Super-Resolution

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Abstract:
The present paper has mentioned theoretical and practical results of application of an instrument of orthogonal transformations based on basis Walsh functions for information compression under transmission of aerospace images through the communication channel into embedded cyber physical systems. Perceval equality has been shown for quasi-two-dimensional representation of two-dimensional signals. Quality of the image restoration has been evaluated depending on the compression ratio. Protocols for transmission of the formed signal have been suggested. Examples and evaluations of restored images have been indicated. In this paper, we propose a novel learning-based image restoration scheme for compressed images by suppressing compression artifacts and recovering high frequency (HF) components based upon the priors learnt from a training set of natural images. The JPEG compression process is simulated by a degradation model, represented by the signal attenuation and the Gaussian noise addition process.

Based on the degradation model, the input image is locally filtered to remove Gaussian noise. Subsequently, the learning-based restoration algorithm reproduces the HF component to handle the attenuation process. Specifically, a Markov-chain based mapping strategy is employed to generate the HF primitives based on the learnt codebook. Finally, a quantization constraint algorithm regularizes the reconstructed image coefficients within a reasonable range, to prevent possible over-smoothing and thus ameliorate the image quality. Experimental results have demonstrated that the proposed scheme can reproduce higher quality images in terms of both objective and subjective quality.

1. Introduction: Basic report

The purpose of image compression is to represent images with less data in order to save storage costs or transmission time. Without compression, file size is significantly larger, usually several megabytes, but with compression it is possible to reduce file size to 10 percent from the original without noticeable loss in quality. Image compression can be lossless or lossy. Lossless compression means that you are able to reconstruct the exact original data from the compressed data. Image quality is not reduced when using lossless compression. Unlike lossless compression, lossy compression reduces image quality. You can't get the original image back after using lossy compression methods. You will lose some information.

Lossless image compression is usually used in artificial images that contain sharp-edged lines such as technical drawings, textual graphics, comics, maps or logos. This is because lossy compression methods produce compression artifacts to images and sharp-edged lines become fuzzy especially when using strong compression. Instead, lossy compression is a good choice for natural images such as photos of landscapes where minor loss on sharpness is acceptable to achieve smaller file size. With the naked eye it is very hard to see any differences between uncompressed natural image and one with compressed by lossy methods if the compression is not too strong.

The most widely used methods of lossless compression in images are run-length encoding (RLE), entropy coding and dictionary coders. RLE is just representing long sequences of same data by shorter form. For example, AAAAAAABBBBCCCCC can be expressed as 7A4B5C. Entropy encoding assigns codes to symbols so that symbols that occur most frequently take the shortest codes. The most common entropy encoding technique is Huffman coding. Dictionary coders build a table of strings and then replace occurrences of them by shorter codes. The LZW (Lempel-Ziv-Welch) algorithm is perhaps the most used dictionary coder and it is used for example in GIF and ZIP file formats.

Lossy compression is usually based on techniques by removing details that the human eye typically doesn't notice. Digital images are composed of pixels that represent color information. When a pixel differs only slightly from its neighbors, its value can be replaced theirs. This will lose some information but it is usually barely noticeable with human eye if the algorithm is good enough. After this e.g. RLE or Huffman coding can be used to compress data. Mostly used lossy compression method is transform coding such as discrete cosine transform (DCT, used in JPEG) or wavelet transform (used in JPEG 2000). Other popular methods are color quantization (reducing the color space) and chroma subsampling. These methods are based on a fact that the human eye is more sensitive to luminance than color, so file size can be optimized by storing more luminance detail than color detail. Also fractal compression is used but it's not so popular.

There are various image formats that implement these compression methods differently. Some of them use only lossless compression and some of them use both lossless and lossy methods or no compression at all. Most common image formats are the following: BMP, JPEG, GIF, PNG and TIFF.
BMP is an uncompressed image format used in Windows and it eats lots of space. JPEG is the most widely used image format that uses lossy compression methods such as DCT and chroma subsampling. It also uses lossless methods such as RLE and Huffman coding but it doesn't actually allow to save in lossless format. JPEG is especially good for natural images.

GIF uses lossless compression algorithm LZW. So, it reduces the file size without degrading the visual quality. But GIF allows only to use 256 colors so it is not suitable for natural photographs which consist from millions of colors. However, quality can be enhanced by using color dithering. GIF is especially good for artificial images that contain sharp-edged lines and few colors. The compression algorithm that GIF uses was patented in 1985 and the controversy over the patent licensing led to development of the PNG image format. PNG uses also a lossless compression called DEFLATE that uses a combination of the LZ77 dictionary coder and Huffman coding. PNG offers better compression and more features than GIF but it doesn't support animation that GIF does. PNG allows to use millions of colors in pictures.

TIFF format is a flexible and adaptable file format. It can store multiple images in a single file. You can choose which compression algorithm to use. TIFF can be used as a container for JPEG or you can choose to use lossless compression such as RLE or LZW. Because TIFF supports multiple images in a single file, multi-page documents can be saved as single TIFF file rather than as a series of files for each scanned page.

There is also a newer version of JPEG called JPEG2000 which also supports lossless compression. It's lossy wavelet algorithms produce slightly better image quality than JPEG (up to 20 per cent plus) but it's not widely used because of some patent issues. Microsoft has also developed "a new generation" image format called HD Photo (formerly Windows Media Photo). Microsoft claims that HD Photo offers a perceptible image quality comparable to JPEG 2000 and produces images more than twice the quality of JPEG.

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There are also SVG graphics which are used to create vector graphics. It is not actually a compression algorithm but it's an XML based markup language. Instead of specifying the color of every pixel as in raster graphics (JPEG, GIF, PNG), SVG uses mathematical expressions to specify coordinates of shapes. SVG images can be extremely small. The image is also scalable because it is vector-based, so you can enlarge the image and it will still look great.

Transmission of images through channels is one of complicated procedures into embedded cyber physical systems: Earth and medium remote sensing, robot vision etc. It is connected with high volume of data transmitted at the breakpoint of transmission capacity for aerospace communication channels. So, search of simple and effective methods and algorithms to decrease redundancy of video data is a current task at present. Now there are a lot of approaches each of which has its advantages and disadvantages: methods of effective entropic coding, evaluation of possibilities to use visual redundancy of static and dynamic images, consideration of direct coding, predictive coding and run length encoding, methods of block and fractal coding, multiple-scale processing of images. However, none of them provides a full and effective solution of the task.

The present paper has suggested to use a method of orthogonal transformations for transmission of images which allows executing a transfer from the space of image representation in pixel coordinates into the space of another parameter, for example, generalized frequency. Besides, a significant effect of image compression and its qualitative restoration can be achieved.

An image compression method eradicates redundant and/or unrelated information, and resourcefully encodes leftovers. Practically, it is frequently essential to toss away both non redundant information and relevant information to attain the essential compression. In any case, the ploy is discovering methods that permit important information to be resourcefully extracted and represented. This paper copes with dissimilar compression methods for comprising the information in an image. The information can be compressed by means of Lossy techniques such as Quantization, Transform coding, Block Transform Coding or Lossless techniques such as Run Length Coding, Lossless Predictive Coding, Multi-resolution Coding. All these techniques have been discussed in this paper and the performance of any technique/method is analyzed on various parameters like MSE and PSNR.

2. Image compression: Preliminary Guideline

Image compression is a type of data compression applied to digital images, to reduce their cost for storage or transmission. Algorithms may take advantage of visual perception and the statistical properties of image data to provide superior results compared with generic data compression methods which are used for other digital data.

3. Lossy and lossless image compression

Image compression may be lossy or lossless. Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, or comics. Lossy compression methods, especially when used at low bit rates, introduce compression artifacts. Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate. Lossy compression that produces negligible differences may be called visually lossless.

4. Various kinds of Methods for lossy compression

- Transform coding – This is the most commonly used method.
- Discrete Cosine Transform (DCT) – The most widely used form of lossy compression. It is a type of Fourier-related transform, and was originally developed by Nasir Ahmed, T. Natarajan and K. R. Rao in 1974. The DCT is sometimes referred to as "DCT-II" in the context of a family of discrete cosine transforms (see discrete cosine transform). It is generally the most efficient form of image compression.

- DCT is used in JPEG, the most popular lossy format, and the more recent HEIF.
- The more recently developed wavelet transform is also used extensively, followed by quantization and entropy coding.
- Reducing the color space to the most common colors in the image. The selected colors are specified in the colour palette in the header of the compressed image. Each pixel just references the index of a color in the color palette, this method can be combined with dithering to avoid posterization.
- Chroma subsampling. This takes advantage of the fact that the human eye perceives spatial changes of brightness more sharply than those of color, by averaging or dropping some of the chrominance information in the image.
- Fractal compression.

5. Different Methods for lossless compression:

- Run-length encoding – used in default method in PCX and as one of possible in BMP, TGA, TIFF
- Area image compression
- Predictive coding – used in DPCM
- Entropy encoding – the two most common entropy encoding techniques are arithmetic coding and Huffman coding
- Adaptive dictionary algorithms such as LZW – used in GIF and TIFF
- DEFLATE – used in PNG, MNG, and TIFF
- Chain codes

6. Other properties

The best image quality at a given compression rate (or bit rate) is the main goal of image compression, however, there are other important properties of image compression schemes:

Scalability generally refers to a quality reduction achieved by manipulation of the bitstream or file (without decompression and re-compression). Other names for scalability are progressive coding or embedded bit streams. Despite its contrary nature, scalability also may be found in lossless codecs, usually in form of coarse-to-fine pixel scans. Scalability is especially useful for previewing images while downloading them (e.g., in a web browser) or for providing variable quality access to e.g., databases. There are several types of scalability:

- **Quality progressive** or layer progressive: The bitstream successively refines the reconstructed image.
- **Resolution progressive**: First encode a lower image resolution; then encode the difference to higher resolutions.
- **Component progressive**: First encode grey-scale version; then adding full color.
- **Region of interest coding**. Certain parts of the image are encoded with higher quality than others. This may be combined with scalability (encode these parts first, others later).
- **Meta information**. Compressed data may contain information about the image which may be used to categorize, search, or browse images. Such information may include color and texture statistics, small preview images, and author or copyright information.
- **Processing power**. Compression algorithms require different amounts of processing power to encode and decode. Some high compression algorithms require high processing power.

The quality of a compression method often is measured by the peak signal-to-noise ratio. It measures the amount of noise introduced through a lossy compression of the image, however, the subjective judgment of the viewer also is regarded as an important measure, perhaps, being the most important measure.

7. Image restoration: a glance view

Image restoration is the operation of taking a corrupt/noisy image and estimating the clean, original image. Corruption may come in many forms such as motion blur, noise and camera mis-focus. Image restoration is performed by reversing the process that blurred the image and such is performed by imaging a point source and use the point source image, which is called the Point Spread Function (PSF) to restore the image information lost to the blurring process.

Image restoration is different from image enhancement in that the latter is designed to emphasize features of the image that make the image more pleasing to the observer, but not necessarily to produce realistic data from a scientific point of view. Image enhancement techniques (like contrast stretching or de-blurring by a nearest neighbor procedure) provided by imaging packages use no a priori model of the process that created the image.

With image enhancement noise can effectively be removed by sacrificing some resolution, but this is not acceptable in many applications. In a fluorescence microscope, resolution in the z-direction is bad as it is. More advanced image processing techniques must be applied to recover the object.

The objective of image restoration techniques is to reduce noise and recover resolution loss Image processing techniques are performed either in the image domain or the frequency domain. The most straightforward and a conventional technique for image restoration is deconvolution, which is performed in the frequency domain and after computing the Fourier transform of both the image and the PSF and undo the resolution loss caused by the blurring factors. This deconvolution technique, because of its direct inversion of the PSF which typically has poor matrix condition number, amplifies noise and creates an imperfect deblurred image. Also, conventionally the blurring process is assumed to be shift-invariant. Hence more sophisticated techniques, such as regularized deblurring, have been developed to offer robust recovery under different types of noises and blurring functions. It is of 3 types:

1. Geometric correction
2. Radiometric correction
3. Noise removal

8. Image Restoration Using Convolutional Auto-encoders with Symmetric Skip Connections

Image restoration, including image denoising, super resolution, inpainting, and so on, is a well-studied problem in computer vision and image processing, as well as a test bed for low-level image modeling algorithms. In this work, we propose a very deep fully convolutional auto-encoder network for image restoration, which is an encoding-decoding framework with symmetric convolutional-deconvolutional layers.

In other words, the network is composed of multiple layers of convolution and de-convolution operators, learning end-to-end mappings from corrupted images to the original ones. The convolutional layers capture the abstraction of image contents while eliminating corruptions. Deconvolutional layers have the capability to upsample the feature maps and recover the image details. To deal with the problem that deeper networks tend to be more difficult to train, we propose to symmetrically link convolutional and deconvolutional layers with skip-layer connections, with which the training converges much faster and attains better results.

9. Image restoration in cryo-electron microscopy

Image restoration techniques are used to obtain, given experimental measurements, the best possible approximation of the original object within the limits imposed by instrumental conditions and noise level in the data. In molecular electron microscopy (EM), we are mainly interested in linear methods that preserve the respective relationships between mass densities within the restored map.

Here, we describe the methodology of image restoration in structural EM, and more specifically, we focus on the problem of the optimum recovery of Fourier amplitudes given electron microscope data collected under various defocus settings. We discuss in detail two classes of commonly used linear methods, the first of which consists of methods based on pseudoinverse restoration, and which is further subdivided into mean-square error, chi-square error, and constrained based restorations, where the methods in the latter two subclasses explicitly incorporates non-white distribution of noise in the data.

The second class of methods is based on the Wiener filtration approach. We show that the Wiener filter-based methodology can be used to obtain a solution to the problem of amplitude correction (or "sharpening") of the EM map that makes it visually comparable to maps determined by X-ray crystallography, and thus amenable to comparative interpretation. Finally, we present a semiheuristic Wiener filter-based solution to the problem of image restoration given sets of heterogeneous solutions.

10. Conclusion

Region-based image coding schemes using heterogeneous quality constraints are especially attractive because they not only can well preserve the diagnostic features in region(s) of interest, but also meet the requirements of less storage and shorter transmission time for medical image imaging applications. The similarity between the reconstructed and original image is more when the SPIHT/SPIHT ROI hybrid scheme is used as reflected by the higher values of PSNR and Correlation. Further, from the experiments it was found that taking two regions i.e., ROI and background and then compressing the image is best than taking image as one region or taking three regions i.e., most significant region, less significant and insignificant region.

Image restoration is a part of digital image processing. Restore the original image from degraded image, if u have clue about degradation function, is called image restoration. The main objective should be estimating the degradation function. Spatial domain techniques are particularly useful for removing random noise. Frequency domain techniques are particularly useful for removing periodic noise.

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