Various Applications of Compressive Sensing in Digital Image Processing: A Survey

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Abstract - *Compressive sensing (CS) is a fast growing area of research. It neglects the extravagant acquisition process by measuring lesser values to reconstruct the image or signal. Compressive sensing is adopted successfully in various fields of image processing and proved its efficiency. Some of the image processing applications like face recognition, video encoding, Image encryption and reconstruction are presented here.*

***Key Words*:** Compressive Sensing, Digital Image Processing.

1.INTRODUCTION

Compressive sensing is a brand new type of sampling theory, It assures the reconstruction of sparse signals and images from the less or incomplete information.

The traditional methods that are used for reconstruction of images needs its sampling rate to be twice the highest frequency. It also states that the total number of measurements for the discrete signal must be greater than or equal to its original length to make sure the reconstruction of the image. But the Compressive sensing states that with few measurements about the signal it is possible to reconstruct the original signal when assumptions or prior knowledge of the signal is available. It takes benefit of redundancy in the signal. Sparsity of the signal plays a major role in compressive sensing. It minimizes the number of number of non zero elements in the signal.

Compressive sensing is a way to achieve a sparse representation of a signal. It is predicated on the idea to take advantage of redundancy (if any) in the signal. Signals like images are sparse, as they comprise, in some representation domain, many coefficients close to or equal to zero. The fundamental of the CS idea is the potential to recover with relatively few measurements [1].

$$y = \varphi x$$

φ – measurement matrix, x – original image, y – measurement results.

The Three stages of compressive sensing are, sparse representation, measurement matrix, and signal reconstruction.

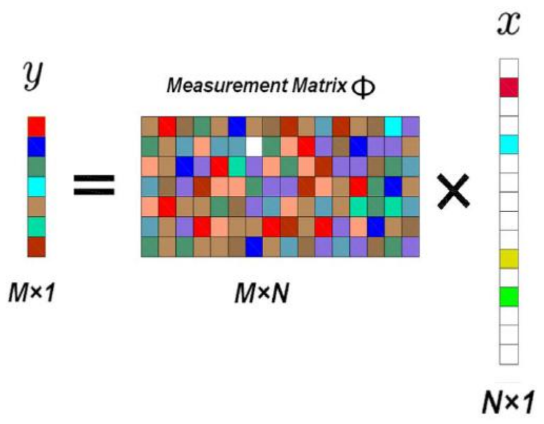

Fig 1: Compressive Sensing sampling process

Compressive sensing is useful when,

1. Signals are sparse in nature.
2. Measurement at transmitting end costs much.
3. Receiver end computation is cheap.

2. COMPRESSIVE SENSING IN VIDEO ENCODING

Comparatively, It proves that applying compressive sensing in video encoding and reconstruction shows better results than other traditional methods. Another advantage of using compressive sensing in video encoding is, its sampling rate is much lower than the Nyquist rate.

First, the inverse discrete cosine transformation is applied to the signal to get the sparsity of the signal then only the compressive sensing can be applied. The total number of nonzero coefficient is much less than the total number of samples.

Second, the measurement or signal projection. This is where the compressive sensing is introduced. Here, Gaussian measurement matrix is used. The pixels that are eligible for next processing block is determined and sampling redundancy is eliminated.

Selection of more number of coefficients means better quality, at the same time it increase the bit size and increased bandwidth requirement.

Third, The basis pursuit algorithm is used for reconstruction. By using convex optimization the signal representations are obtained by the basis pursuit with the help of dictionaries. For reconstruction, L1 minimization is used to estimate the original signal [2].

A. Compressive Video Sensing

1. Frames are divided in to blocks
2. Frame is gone through a test to determine its type (Reference or Non Reference)
3. Reference frame is set high measurement rate and going through intra-frame coding.
4. Non Reference frame is set lower measurement rate and to eliminate the redundancy in these frames, motion compensation is done.

4. COMPRESSIVE SENSING IN AFM IMAGING

Atomic Force Microscopy is used to sense the surface of an atom or cell with the help of piezoelectric elements. By measuring the hardness of the cell, cancer cells can be identified when comparing with the normal cells.

Here, the sample is scanned line by line from the top of the sample and the topography of the sample is obtained.

The AFM employs fast scanning over the sample. It takes minutes to successfully obtain an image of the sample. When live cells are observed, the changes can happen within a second. This is where the compressive sensing is introduced which ensures reduced scanning time in Atomic Force Microscopy.

Compressive sensing uses the compressed scan rather than the complete surface is being scanned. It uses less measurements compared to the traditional methods. The three steps involved in compressive sensing are sparse representation, projection or measurement and reconstruction.

Compressive sensing is effective only when the signal is sparse. When the signal is not sparse in nature there is a need of some transformation to represent the signal as sparse.

The sparse coefficients of the signal can be identified in the dictionary. Greedy search and matching pursuit algorithms are used to find the sparse optimization.

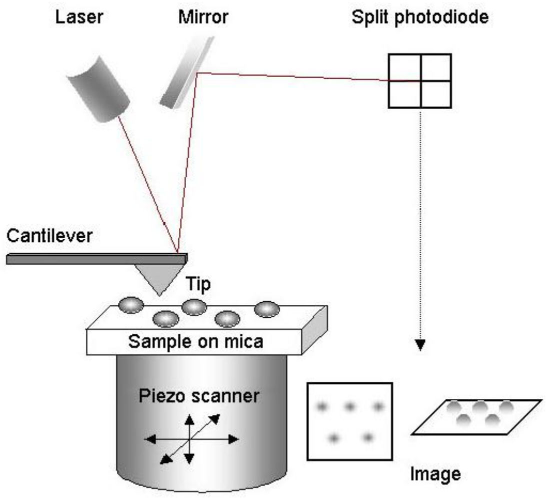

Fig 2: Atomic Force Microscopy

The Compressed scan always updates the surface of the sample. Reconstruction of image starts when obtaining topography data by scanning [3].

3. COMPRESSIVE SENSING IN IMAGE ENCRYPTION

The term compressive sensing is defined as projection of signal into a sensing matrix to reduce the size of the signal. Compressive sensing provides encryption mechanism because the reconstruction of the signal needs sensing matrix and the dictionary.

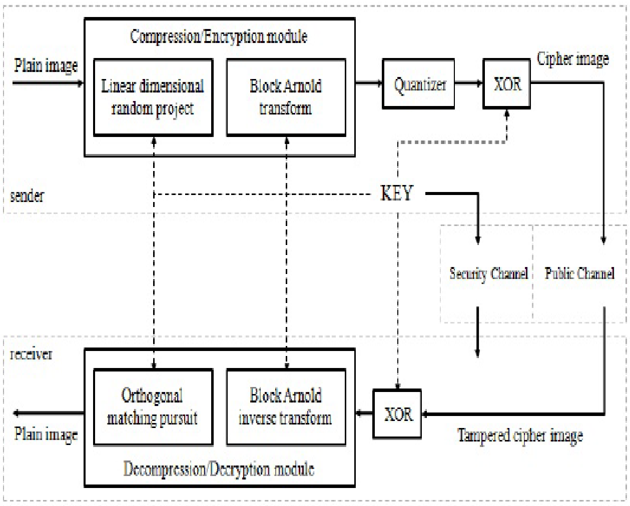

Fig 3.1: Image Encryption using Compressive Sensing.

With compressive sensing, simultaneously compression and encryption is done. Ensuring security over data transmission is very important as it contains valuable data. Encryption is the well known mechanism for data security. Encryption is done only after the compression of data when the bandwidth channel is low and it takes considerable energy for transmission in an embedded system.

With the compressive sensing, it takes only fewer measurements to reconstruct the original signal when comparing the traditional methods [4].

4. COMPRESSIVE SENSING IN MISSING AREA RECONSTRUCTION

Depending on the end-consumer requirements, clouds in remotely sensed imagery can also or might not represent an undesirable supply of noise. In case they're viewed as a noise supply, numerous methodologies have been developed within the past so as to cope with this trouble. Normally, the commonplace approach first detects the contaminated regions and, in a second instance, tries to dispose of the clouds by means of substituting them with cloud-loose estimations.

With the help of Compressive Sensing, We can recover an unknown sparse signal from a small set of linear projections. Through exploiting this new and critical end result, we can attain equivalent or better representations by using the use of much less measurements compared with other methods [5].

The three methods to clear up the trouble of the reconstruction of missing statistics due to the presence of clouds are,

1. Basis Pursuit – Uses L1 Normalization for convexification of the problem

2. Orthogonal Matching Pursuit – Improved Solution of Matching Pursit (MP), where elements with the highest correlation are selected and separated and then the iteration follows with the remaining elements.

3. Genetic Algorithm – Best Solution is selected from multiple candidate solution and applied with the help of genetic operators and fitness function.

5. CONCLUSIONS

This paper presents a comprehensive survey of the compressive sensing and its various applications. Areas like Image Compression, encryption, Nano Imaging and Missing area reconstruction were studied, where compressive sensing is adopted to achieve better results.

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