TECHNIQUES FOR IMAGE SUPER RESOLUTION - A SURVEY

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Abstract: Super resolution is a method of creating high resolution image from low resolution image. This paper describes various existing methods for super resolution and need of super resolution in now a day. A comparative study is presented based on survey.

Keywords: Low-Resolution (LR), High-Resolution (HR), Super resolution (SR):–Obtaining a HR image from one or multiple LR images.

I. INTRODUCTION
Super resolution method is an effective method in order to generate a high-resolution (HR) image using one or more low-resolution (LR) observations from the same scene [17][2]. HR image can be created by different hardware devices like charge-coupled devices (CCD) and CMOS image sensors, digital cameras but this approach leads to a high cost which is not always affordable to every class of people [9]. In most electronic imaging applications high resolution (HR) images are required [17]. HR image can offer more details that may be critical in various applications [1]. The desire for high resolution images from two principal application areas: improvement of pictorial information for human interpretation and helping representation for automatic machine perception. Super resolution is highly required now a days in many fields. Super resolution techniques can be classified into categories like interpolation based, reconstruction based, learning based. Interpolation methods are simple and fast. No additional information is offered by this approach. High resolution(HR) image generated by single low resolution(LR) is quite challenging because less information is available due to single image, while in case of multiple low resolution(LR) image more detail is available. Reconstruction based approach uses prior knowledge to generate high resolution image. Learning based approach uses multiple low resolution images.

A. Applications of super resolution
- Medical imaging
  In medical imaging super resolution is helpful to make correct diagnosis and treatment [1]. In magnetic resonance imaging (MRI), computed tomography (CT), mammography super resolution is very helpful.
- Video surveillance ,video printing
  Degraded quality video having mixed resolution can be enhanced with super resolution [8]. Higher quality of images can be generated by digital camera obtained by inexpensive LR cameras [3].SR is required in converting signals for HDtv [4][9].
- Traffic surveillance

Super resolution is helpful in traffic analysis when it is combined with segmentation technique. Synthetic zooming of region of interest (ROI) is another application of super resolution.
- Satellite imaging
  Images captured by satellite often need to be enhanced due to poor results [5][2]. Some times no. of images are available for same area and some target is needed with improved resolution [1].

B. Challenges in super resolution
- Robustness
  Robustness is required in super resolution method. Method in [4] does not provide unique result.
- Performance
  Classic interpolation methods are fast while reconstruction methods have high computational cost [4]. Performance of a method is also referred as a quality of a resultant image.
- Computation efficiency
  Computation efficiency affects the performance of super resolution method.
- Image registration
  Image registration is critical for the success of multi frame SR reconstruction [8], where complementary spatial samplings of the HR image are fused. The image registration is a fundamental image processing problem that is well known as ill-posed. The problem is even more difficult in the SR setting, where the observations are low-resolution images with heavy aliasing artifacts. The performance of the standard image registration algorithms decreases as the resolution of the observations goes down, resulting in more registration errors. Artifacts caused by these registration errors are visually more annoying than the blurring effect resulting from interpolation of a single image.

II. SUPERRESOLUTION METHODS
A. Kernel Resize Approach
It is a classic way of super resolution. In this approach base function or interpolation kernel is used. Base functions like bi-linear, bi-cubic, spline, lanczos are generally used to approximate continuous function for making up the image. If linear kernel is used for approximation it is known as bi-linear interpolation[10]. Same way if cubic kernel is used it is known as bi-cubic interpolation. This kind of approach is non-adaptive interpolation [9]. In this approach for
interpolation all pixels of an image are treated equally. Non adaptive algorithms are bi-linear, bi-cubic, nearest neighbour, spline, lanczos. Implementation of approach usually multiplies pixel locations with kernel function and then it is multiplied by known discrete sample. Same process is repeated for all locations of pixels. Adjacent pixels ranging from 0 to 256 are used for interpolation. Bilinear Interpolation [10] is an extension of linear interpolation. Bilinear Interpolation determines the grey level value from the weighted average of the four closest pixels to the specified input coordinates, and assigns that value to the output coordinates. In this interpolation is performed on one direction then again in the other direction. For one-dimension Linear Interpolation, the number of grid points needed to evaluate the interpolation function is two. For Bilinear Interpolation (linear interpolation in two dimensions), the number of grid points needed to evaluate the interpolation function is four. It provides good quality of image but when more concentration is needed it produces blurring effects.

Nearest Neighbour Interpolation [14] Nearest Neighbour Interpolation, the simplest method, determines the grey level value from the closest pixel to the specified input coordinates, and assigns that value to the output coordinates. It should be noted that this method does not really interpolate values, it just copies existing values. Since it does not alter values, it is preferred if subtle variations in the grey level values need to be retained. For one-dimension Nearest Neighbour Interpolation, the number of grid points needed to evaluate the interpolation function is two. For two-dimension Nearest Neighbour Interpolation, the number of grid points needed to evaluate the interpolation function is four. Resampling by using kernels is easy and effective approach but it is not always optimal in terms of quality. It has disadvantage like blurring of sharp edges, introducing blocking artifacts. It performs well in smooth area but not in edge area. Inability to generate fine details.

B. New Edge directed Interpolation

Image interpolation addresses the problem of generating a high resolution image from its low resolution version. Linear interpolation schemes like bilinear, bicubic are the conventional interpolation schemes. They are simple and fast to implement [6][7]. Computational complexity is low. Linear interpolations are generally used for computational simplicity not for the performance. In New edge directed interpolation[7][6] value of pixel is estimated based on interpolation. Brief explanation of this algorithm is as follows.

It is assumed that low resolution image X \( i \) of size H*W directly comes from of size 2H*2W. i.e. \( Y_{2,2} = X_{i,j} \). Suppose \( Y_{2i+1,2j+1} \) interfacing lattice interpolated from the lattice \( Y_{2i,2j} = X_{i,j} \) (fig.2.1). Interpolation includes four nearest neighbors along the diagonal directions. The covariance between neighbouring pixels in a local window around the low resolution source is used to estimate the covariance between neighbouring pixels in the high resolution target. The covariance used is that between pixels and their four diagonal neighbours. The covariance between low resolution pixels and their four diagonals in a m*n local window is calculated. This covariance determines the optimal way of blending the four diagonals into the centre pixel. This optimal value in the low resolution window is used to blend a new pixel in the super-resolution image. By using the local covariance, the interpolation can adhere to arbitrarily oriented edges to reduce edge blurring and blocking. After this interpolated value of \( Y_{2i+1,2j+1} \) can be obtained. NEDI[6][7] is further extended with iNEDI [7][improved NEDI]. Both NEDI and iNEDI are having computational complexity higher than the many learning based methods. It requires about thousands of multiplications per pixel. So applying this approach computational complexity is increased by two orders of magnitude when compared to that of linear interpolation[6].

C. Iterative curvature based interpolation(ICBI)

In this method (ICBI) [7] higher resolution grid is generally filled in two steps. In first step pixels indexed by two odd values (e.g., darker pixel in fig.2.2(a)) are computed as a weighted average of the four diagonal neighbors (corresponding to to pixels of the original image) and in the second step the remaining holes (e.g., black pixel in fig.2.2(b)) will be filled with the same rule as a weighted average of the four nearest neighbors in horizontal and vertical directions. For the first step following equation is used.

\[ I_{2i+1,2j+1} = \alpha \cdot (I_{2i,2j}I_{2i,2j+2}I_{2i+2,2j+1}I_{2i+2,2j+3}) \]

After value of the new pixel is computed define an energy component at each new pixel location that is locally minimized when the second order derivatives are constant. Then interpolated pixel is modified in iterative greedy procedure trying to minimize the global energy. Same procedure is repeated after the second interpolation step.

Fig. 1 Geometric duality when interpolating Y2i+1,2j+1 from Y2i,2j[6]

Fig.2 Two step interpolation based on a weighted average of four neighbor[7].

ICBI[7] is extremely effective in removing sampling artifacts even if it does not enhance strong lines and contrasted edges and results appear over smoothed. This method can be implemented on low level language which is allows to write, execute and upload code to reduce computing time.
D. Orthogonal matching pursuit (OMP)
Orthogonal matching pursuit (OMP) [2] algorithm can be used for SR reconstruction stage. This algorithm selects an atom which is the most correlated with the current residuals at each step for obtaining the sparse representation. Effectiveness and simplicity is provided by OMP [2] when initial estimation of HR image is needed based on sparse representation. Finding solution for such kind of situation is NP-hard problem. Many approximate methods have been proposed to solve it [2].

E. Projection onto convex sets (POCS)
Projection onto convex sets (POCS) [4][1] is an alternative iterative approach in which prior knowledge about the solution of reconstruction process is incorporated. It is first suggested by stark and oskoui [2]. Then extended by Tekalp et al. POCS can generate better results in the background with relatively more accurate motion registration over MAP method [4]. POCS algorithm has many advantages like simplicity; it can be applied to the occasion with any smooth movement, and can easily join in the prior information, so this method is widely used. Restriction in becoming a part of closed convex set Ci is generated due to incorporating a priori knowledge into the solution. Ci is defined as a set of vectors. The relaxation operator will be used to replace ordinary projector operator, at the same time it is not contributing to the resumption of the edge and details of images. This method has a disadvantages for e.g. non-uniqueness of solution, high computational cost and slow convergence [1][4].

F. Nonuniform interpolation
The basis of non-uniform interpolation [1] super-resolution techniques is the non-uniform sampling theory which allows for the reconstruction of functions from samples taken at non-uniformly distributed locations [1]. Early super-resolution applications used detailed camera placement to allow for accurate interpolation, because this method requires very accurate registration between images. A new method was developed to overcome the limitations of insufficient registration accuracy by applying multiple digital sensors with different pixel sizes [1], [7]. This ensures that pixels of multiple images will not coincide regardless of camera placement. Non-uniform interpolation is a basic and intuitive method of super-resolution and has relatively low computational complexity, but it assumes that the blur and noise characteristics are identical across all low-resolution images as shown in figure 2.3 [1]. Figure 2.4 [1] shows results obtained by various interpolation methods for super resolution of image.

The advantage of this approach is that it takes relatively low computational load and makes real-time applications possible [1], [7]. However, in this approach, degradation models are limited they are only applicable when the blur and the noise characteristics are the same for all LR images [1].

G. Example based approach
In this approach [8][12] image which is to be enlarged is divided into no of patches. Patches are the part of an image and represent detail of an image. After breaking down an image high resolution detail is searched through patches. Sometimes for high resolution detail a local patch does not provide sufficient information. So it is disadvantage of this method. Another disadvantage of this approach is to find a closest examples for the input patch searching from large database (having thousands of patches) is required and most of them looks similar so difficult to mach them.

So this approach of local patch is not sufficient. Alternative is identified by concentrating on relationship between neighbouring high resolution patches [8][12]. Example based approach gives a good result. But it is time consuming approach.
III. CONCLUSION

Classic interpolation techniques like bilinear and nearest neighbour are simple but output is blurred image. NEDI can produce good quality image than classic interpolation techniques but has high computational coast. Other reconstruction and example based techniques also time consuming. ICBI method is able to remove sampling artifacts and can be used for real time applications.

REFERENCES


