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Zooming Techniques for Digital Images: A survey

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Abstract
Scaling operation plays an important role in resizing digital images. Scaling is used to perform shrinking (subsampling) and zooming (oversampling) on digital images. Zooming implies enlargement or magnification of an image for better view. Theoretically, the paper presents broad categorization and comparison of image zooming techniques. Various techniques range from traditional pixel replication, interpolation and advanced techniques based on fuzzy logic. A combination of fuzzy and interpolation gives best results. From implementation point of view PSNR and SSIM are used to compare the performance of these techniques.

Keywords
Zooming, PSNR, SSIM, Interpolation, Fuzzy Logic

I. Introduction
Today, image processing is one of the most rapidly growing technologies. Basically there are two methods of processing an image:

A. Analog Image Processing
Analog image processing implies amendment of an image by using electrical means. For example television imagery.

B. Digital Image Processing
Digital image processing makes use of digital computers to process an image. In digital image processing we require two types of information; either the whole input image or some interested information from the user point of view like radius, objects etc. There are various advantages of using digital image processing like preservation of original data accuracy, flexibility and repeatability. Digital image processing includes scaling of image as an important area. Scaling operation plays an important in resizing digital images. Scaling is used for shrinking or zooming of an image. Shrinking is also known as subsampling or reduction of an image. Shrinking is used in compression and thumbnails view of images. While performing subsampling, the numbers of pixels in the original image are reduced and this reduction is done by replacing the group of pixels by random chosen pixel values from this group. Interpolation is used to find the value of unknown pixels with the help of known pixel values. There is wide variety of image interpolation methods available.
Technically, Zooming implies enlargement or magnification of an image for a better view of it. In digital image processing, image zooming is known as oversampling. Zooming is a process of creating new location of pixels and to assign values to new locations. A zooming algorithm takes an image as input and generates a picture of larger size. A zooming algorithm is characterizing good if the required information is acquired after zooming process. PSNR and SSIM are measures to evaluate the quality of zoomed image. PSNR (peak signal to noise ratio) is a quantitative measure, which is used to compare the quality of an original and zoomed image. SSIM (structure similarity index) is a qualitative measure and it is used to find the similarity between two images.
Rest of the paper is organized into six sections. Section II describes various zooming applications and reasons that make zooming an area of research. Section III describes the broad categorization of zooming techniques from traditional techniques till advanced techniques. Section IV presents a comparative study of various zooming techniques. Also this section presents the factors that make this classification better. Section V concludes the paper.

II. Required Characteristics of Zooming Techniques
Zooming is used for several purposes like image reconstruction, improving image display for humans, reducing artifacts, correcting for geometrical distortions introduced by the optical subsystem, obtaining sub pixel accuracy and computing the new pixel position for rotation. There are following issues that make zooming operation an area of research:

A. Speed
Zooming operation requires an image to be enlarged at one click of a button as slow zooming irritates the user.

B. Clarity
Sharpness of the image must be retained.Various regions should appear as distinct as in original image.

C. Smoothing
The neighboring pixels must have continuity in color except for the edges.

D. Memory requirement
Zooming operations result in high complexity in space. Hence, an implementation of zooming operation must handle this problem effectively.
Applications of image zooming range from crime suspect detection, robotics, vehicle number plate identification, distant targets identification as an on-line dynamic vehicle routing, a forensic image processing environment for investigation of surveillance video to CCTV in an airport car-park and shopping malls etc.

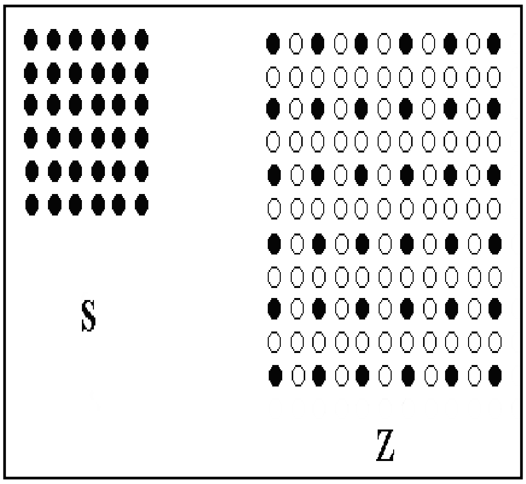

Fig. 1: Pixel Position of Original(S) and Zoomed (Z) Image with Zooming Factor 2.

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III. Categorization of Image Zooming Methods

There has been lot of research from traditional techniques from 90's till today's advance techniques. There are various image interpolation methods. Image interpolation is the most acquainted and most widely used technique. Basically, image interpolation techniques are divided into 3 broad categories: linear [1], non-linear [3, 4] and variational.Some linear interpolation methods are bilinear, bicubic, quadratic zoom, zero padding, B-Spline etc. The most advanced techniques are - a combination of fuzzy logic and traditional interpolation methods.

IV. Zooming Techniques-A Comparative Study

Beginning from traditional techniques till advanced techniques, it is not an objective task to compare these methods. Different applications have different requirements. But one way is to compare these techniques based on output of interpolated image. There are two criteria to compare these techniques: first are visual properties and second is computational complexity.

A.Visual Properties

1. Contrast Invariance

The method should preserve the luminance values of objects that are present in image and maintain the high contrast of an image.

2. Geometric Invariance

The method should preserve the geometric features, subjective matter and size of objects of an image.

3. Over-Smoothing

The method should not give rise to blocky regions in an image.

4. Edge Preservation

After applying the method the boundaries, sharpness and edges should be retained.

5. Noise

the method should not produce noise in the resulted image. The method should work for noisy and noise free images also.

6. Application Awareness

Different applications have different requirements like efficiency, clarity, quality, sharp edges. The method should serve the purpose. For example some application demands high quality in resulted image like medical images.

B. Computational Property

1. Sensitivity to Parameters

The method should be generalized enough such that its performance should not vary as the internal parameters of images vary. These methods range from replication [10], fractal based [1], nearest-neighborhood interpolation [2], bilinear [3], bi-cubic, cubic-spline [4], curvature-interpolation [5], Sinc, b-spline [6, 7], wavelet-based [8], LLE based [8], Fuzzy logic based [9] and others. Table 1, explains various methods, with key idea, describing their advantages and disadvantages.

Table 1: A Comparative Study of Image Zooming Techniques With Their Key Idea, Advantages and Disadvantages

Sr. No.	Technique	Key idea	Advantages	Disadvantages
1.	Replication method	It is ZOH (zero order hold) method. Pixel repetition along scan line is followed by scan line repetition.	Less complexity	From implementation point of it is not an optimal choice.
2.	Fractional based zooming	It uses multi-resolution property of images for zooming.	Subjective quality, superior to pixel replication. It is used for extreme enlargements.it preserves the shape and precision of the original image.	Decision must be made about fractional part, not suitable for applications that require sharp edges.
3.	Nearest –Neighborhood method	It considers least nearest pixel to the interpolated point. Only one pixel is used to compute the value of unknown point.	Enhanced speed, least processing time because one pixel is used to find the value of interpolated point.	Check board effect, worst quality.

4.	Bilinear	2*2 neighborhoods are used to calculate the value of unknown pixel. Total number of pixels is four whose weighted average is compute to find the value of interpolated point. This gives smoothness in resulted image as compare to nearest neighborhood method.	Good quality of images after zooming, smoother images.	Does not suitable for applications where more concentration is given on edges because it creates jagged effects end to end edges. This method produce ringing artifacts, the method may produce blurring effects because of weighted average of neighborhood pixels.
5.	Bi-cubic	4*4 neighborhoods are considered for calculating the value of interpolated point. Total number of pixels is 16 and these are at varying distance from interpolated point. The closet pixels to the interpolated point are given higher weights than the farthest pixels.	Sharper images, ideal combination of quality and processing time of zoomed image, standard method for image editing.	Uneven results along edges. Ringing artifacts, introduce blurriness in image because weighted average method is used.
6.	Cubic Spline	Fits cubic-spline to existing image points. Fitted spline provides intensity values for the generated pixels.	Good quality, use in the applications where the image formed by positive intensity values and velocity of sound is positive like tomography etc.	Edges are not clear and shadowed luminous contrast, poor efficiency.
7.	Curvature Interpolation Method	Uses curvature features to compute zoomed pixels intensities.	Based on curvature feature of an image, clear images with sharp edges, well work for noise free images .Reduce image blur and the checkerboard effect, easy to implement.	Unknown
8.	Sinc	Higher order interpolation algorithms .it considers more number of pixels for finding the value of interpolated point.	Retain most of the contents of original image.	Increased processing time.
9.	B-spline	A piece-wise B-spline function is used to fit spline over the existing pixels.	Fastest technique, best results in similarity matching to the original image, sufficient for practical applications, higher quality and resolution.	Numerical complexity increases as the size of kernel increases.
10.	Wavelet based interpolation	Image pixels are interpolated using wavelets.	Doubles the resolution of an image, conserve the edges and their sharpness.	Not work well on texture feature of an image.

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11.	LLE (Locally linear embedding) based technique	Locally linear embedding algorithm is used to interpolate image patches by finding close matches in a training set.	Works well for zooming textured images.	Technique is very sensitive to the training set used.
12.	NL (Non local) means interpolation techniques	Non local technique that uses global information.	Suitable for large textured images, simultaneously interpolate and remove noise.	Sensitive with respect to parameters, sometimes fine structures are also removed, introduce blurriness in resulted image.
13.	PDE based interpolation	Partial Differential Equations based approach.	Conserve edges and their smoothness.	Change in contrast levels, sometimes over smoothed edges.
14.	Fuzzy logic based interpolation methods	A combination of interpolation techniques and fuzzy logic is used to calculate the value of interpolated point the Euclidean distance in the linear interpolation is replaced by fuzzy adapted distance. Basically fuzzy rules are used for finding the value of interpolated point.	These methods enhance linear interpolation methods by using advanced techniques. More clarity.	No clear known disadvantages.

V. Conclusion

Linear interpolation methods are not suitable for edge concentrated application. Because no special treatment is given to edges while zooming. These methods are not suitable for best visual quality data. Non-linear interpolation methods are used to overcome the problems of linear interpolation methods. Non-linear methods are suitable for edge enhancement applications. The techniques that consider more number of pixels while computing the value of unknown points in zoomed image produce better results than the methods that consider less number of pixels. Higher order methods give better results than other methods but in much cases computational complexity increases. Best results can be achieved with the combination of fuzzy and interpolation techniques.

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