Seam Carving Approach for Multirate Processing of Digital Images

Madhukar. B. N.[1], Aravinda. K.[2], K. S. Madhu Babu[3], Manoranjan. B. R.[4]

[1,2] *Sr. Assistant Professor, ECE Dept., New Horizon College of Engineering, Bengaluru – 560103, India*
[3,4] *M.E. (Applied Electronics) Student, SEC, Anna University, Kanyakumari – 629301, India*

***Abstract*: - This paper presents a new approach called Seam Carving for multirate signal processing of digital images. Increasing and decreasing the sizes of digital images are common place in day-to-day image processing. These methods involve long procedures and sometimes consume more time for getting implemented. Whereas, using the Seam Carving method eradicates the excess time involved in upsampling and downsampling a digital image considerably as this method is straightforward and simple to implement. This method comes in handy when we are dealing with large medical images and remotely sensed images. This technique is applied on standard images and its performance is analyzed. The entire work was implemented using Matlab R2017a software package.**

Keywords – seam, image, upsample, downsample.

I. INTRODUCTION

Seam Carving method is one of the latest digital image processing techniques that are used for expanding and decimating the digital images. It is essentially a content-aware image resizing algorithm that was invented by Shai Avidan and Ariel Shamir in 2007 [9]. The seam carving algorithm is also called Liquid Rescaling algorithm. Since images, including bitonal and colour, are multidimensional, Seam Carving algorithm is also essentially a multidimensional digital image processing algorithm that is applied in both the spatial and frequency domains.

Seam Carving method works on the principle of computing the paths of least importance referred to as seams in a digital image. Expanding an image comprises of seams being inserted into it whereas, decimating an image comprises of seams being eradicated from it respectively [10]. The liquid rescaling method enables manually defined arenas in which pels may not be modified, and features the ability to eradicate objects in entirety from the digital image. This method is used for properly displaying images without any distortion on different projection media.

Seam can be either in horizontal and vertical directions. A horizontal seam is defined as the path of pels connected from left to the right in an image whereas the vertical seam is defined as the path of pels connected from top to the bottom in an image with one pel in each row. The energy function of a pel is computed by measuring the contrast with its neighbouring pels [1]. It is nothing but the computation of the path of minimum energy cost from one end of the image to another. This can be done using various procedures such as Dijsktra's algorithm and Graph Cuts (taken from Graph Theory), Dynamic Programming and Greedy algorithm (taken from Engineering Optimization), etc [2].

II. MATHEMATICS OF SEAM CARVING

We develop the theory related to seam carving from a monochromatic image point of view. Let $\mathbf{K}$ be an $n \times m$ discrete monochromatic image. Seam Carving is nothing but eradicating pels in a judicious way. The energy function corresponding to this is written mathematically as under [3],

$$\mathfrak{E}_1(\mathbf{K}) = |\frac{\partial}{\partial x}\mathbf{K}| + |\frac{\partial}{\partial y}\mathbf{K}| \quad \ldots (1)$$

We normally look for preserving both the shape and the visual coherence of the input image while applying the seam carving procedure. Hence, it is desirable to check for the size of the target image that should contain the highest energy. Hence, for doing seam carving, it is desirable to have a resizing operator that has the tenacity to preserve the information inherent in the digital image better than the removal of pels [4].

The vertical seam is defined by the equation,

$$\boldsymbol{\mathcal{H}}^{\mathbf{x}} = \{h_t^x\}_{t=1}^n = \{(x(t), t\}_{t=1}^n, \forall t, |t(i) - t(i-1)| \leq 1 \quad \ldots (2)$$

Here, x is a mapping $x: [1, \ldots, n] \to [1, \ldots, m]$. Hence, a vertical seam is an 8-connected path of pels in the image from to bottom that has only one pel in each row of the image. Similarly, if y is a mapping $y: [1, \ldots, m] \to [1, \ldots, n]$, then, the horizontal seam is defined by the equation [5],

$$\boldsymbol{\mathcal{H}}^{\mathbf{y}} = \{h_u^x\}_{u=1}^m = \{(u, y(u))\}_{u=1}^m, \forall u, |y(u) - y(u-1)| \leq 1 \quad \ldots (3)$$

The pels of the path of seam $\boldsymbol{\mathcal{H}}$ is given by the expression, $\mathbf{K}_{\mathcal{H}} = \{\mathbf{K}(h_t\}_{t=1}^n = \{\mathbf{K}(x(t), t\}_{t=1}^n$. Removing the pels of a seam from an image corresponds to pels being translated either left or up for compensating the missing path.

If we designate the energy function by $\mathfrak{E}$, then, the cost of the seam is defined by the expression [6],

$$\mathbb{E}(\mathcal{H}) = \mathbb{E}(\mathbf{K}_{\mathcal{H}}) = \sum_{t=1}^{n} \mathfrak{E}(\mathbf{K}(h_t)) \quad \dots (4)$$

The aim is to find the optimal seam h^* that should minimize the seam cost given in Eq. (4). This gives,

$$h^* = \min_h \mathbb{E}(\mathcal{H}) = \min_h \sum_{t=1}^{n} \mathfrak{E}(\mathbf{K}(h_t)) \quad \dots (5)$$

The optimal seam is found using optimization methods such dynamic programming [7]. Normally, this is done by traversing the input image from the second row to the last row and then calculating the cumulative minimum energy $\mathbb{M}$ for all possible connected seams for each entry (t, u) given by the equation [8],

$$\mathbb{M}(t,u) = \mathfrak{E}(i,j) + \min(\mathbb{M}(t-1, u-1), \mathbb{M}(t-1, u), \mathbb{M}(t-1, u+1)) \dots (6)$$

Finally, the minimum value of the last row in $\mathbb{M}$ shows the end of the minimal connected vertical seam. This gives the optimal seam path. The advantages is that the energy in the decimated and the upsampled images are preserved which makes this seam carving technique an attractive approach in multirate filtering of digital images [9].

III. RESULTS AND VALIDATION

Fig. 1 shows the input (cameraman) image of size 256 x 256 in tif format. Fig. 2(a) shows the decimated image of the same which is of size 128 x 128 and Fig. 2(b) shows the expanded image of the same input which of size 512 x 512, by a factor of 2 each. The times taken for performing the upsampling and downsampling operation for the coins.png image are 1.225 second and 0.234 seconds respectively. The artefacts that are normally seen while applying traditional multirate signal processing techniques, such as, blocking and ringing are not seen in the output images.

Fig. 3 shows another input (coins) image is of size 246 x 300 in png format. Fig. 4(a) shows the decimated image of the same which is of size 123 x 150 and Fig. 4(b) shows the expanded image of the same input which of size 492 x 600, by a factor of 2 each. The times taken for performing the upsampling and downsampling operation for the coins.png image are 1.403 second 0.351 seconds respectively. There are no blocking and ringing artefacts in the output images.

Fig. 5 shows another colour input (street) image is of size 480 x 640 x 3 in in png format. Fig. 6 shows the decimated image of the same which is of size 240 x 320 x 3 and Fig. 7 shows the expanded image of the same input which of size 960 x 1280 x 3, by a factor of 2 each. The times taken for performing the upsampling and downsampling operation for the coins.png image are 2.301 second 1.451 seconds respectively. There are no blocking and ringing artefacts in the output images.

Fig. 3 Input Image (cameraman).

(a) (b)

Fig. 2 (a) Output Image for Upsampling (b) Output Image for Downsampling

Fig. 3 Input Image (coins).

(a) (b)

Fig. 4 (a) Output Image for Upsampling (b) Output Image for Downsampling.

Fig. 5 Input Image (street)

Fig. 6 Decimated Image (Street).

Fig. 7 Upsampled Image (Street).

IV. CONCLUSION AND FUTURE SCOPE

One of the forefront advantages of Seam Carving procedure is that it can be accomplished fully in the spatial domain itself. Hence, it is directly possible for us to apply the upsampling and downsampling operations the image directly without any artefacts. The same upsampling and downsampling operations in multirate digital signal processing give artefacts such as imaging and aliasing effects which make it mandatory to make use of a Lowpass Filter for eradicating them; this is an extra block which would add on to the cost of implementation of the system. Thus, seam carving overcomes this major bottleneck easily thereby proving its advantage over conventional multirate digital signal processing techniques. Applying Seam Carving on images does not produce unwanted artefacts like blocking and ringing. Seam Carving can be extensively used in the processing of remotely sensed imagery, medical image processing, seismic signal processing, etc.

Seam Carving comes in as handy tool for the upsampling and downsampling of colour images. In normal operations, it is of common practice to split a colour image into three monochromatic images of three colour planes, process each monochromatic image separately, and then concatenate the processed three output images into a single colour output image. This traditional approach takes large amount of computation time and cost. Seam Carving can be easily applied for the multirate digital processing of colour images as it has the tenacity to process colour images direcly thereby saving computation time to a considerable extent. This is a major plus point of Seam Carving over the conventional colour image processing techniques currently existing in the technical literature.

One of the shortcomings of Seam Carving algorithm is that the programmer needs to supply more information for minimizing errors. The remedy is painting the regions that need to be maintained in the output image. Another shortcoming is the removal of a seam corresponding to lesser energy which may lead to the occurring of a seam with a larger energy. The remedy for this pitfall is first to check the simulation of the seam removal and then computing the energy and seeing if it is incremented or not; if so, other seams are selected and the previous one is neglected. Seam removal while decimating an image can lead to spectral foldover or spectral overlap or aliasing which needs to be removed by applying a low pass filter called Antialiasing filter. Jagged edges are a nuisance in the case of images which are having not so smooth areas. Seam Carving does not have the tenacity to conserve Region Of Interests (ROIs) that need to be processed.

Further work can be done on developing advanced algorithms for detecting energy functions accurately at a fast rate. Suitable algorithms need to be developed to performing multioperator functions such as the combination of cropping and scaling operations. Since the removal of multiple seams is rather slow, fast algorithms need to be developed in this regard. The usage of seam carving method need to be applied for time varying videos and their performance analyzed. On-demand server side seam carving techniques need to be developed for future applications for IoT, etc.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Mohan Manghnani, Chairman, New Horizon Education Institution, for providing the necessary infrastructure and encouragement for carrying out this research work. They owe a debt of gratitude to Dr. Manjunatha, Principal, New Horizon College of Engineering, for his constant encouragement. They are grateful to the management of SEC, Kanyakumari, for their support. They are also thankful to their parents for enforcing enthusiasm and passion for research in them.

REFERENCES

[1]. Alan V. Oppenheim, Alan S. Willsky, and S. Hamid Nawab, "Signals and Systems," 2nd Edition, Pearson Education, Inc., New Delhi, India, 2009.
[2]. Simon Haykin, and Barry Van Veen, "Signals and Systems," 2nd Edition, Wiley India Private Limited, New Delhi, India, 2015.
[3]. Alan V. Oppenheim, and Ronald W. Schafer, "Discrete – time Signal Processing," 3rd Edition, Pearson Education, Inc., New Delhi, India, 2009.
[4]. John G, Proakis, and Dimitris G. Manolakis, "Digital Signal Processing," 4th Edition, Pearson Education, Inc., New Delhi, India, 2007.
[5]. Rafael C. Gonzalez, and Richard E. Woods, "Digital Image Processing," 3rd Edition, Pearson Education, Inc., New Delhi, India, 2012.
[6]. Anil K. Jain, "Fundamentals of Digital Image Processing," 1st Edition, Pearson Education, Inc., New Delhi, India, 2013.
[7]. Tamal Bose, "Digital Signal and Image Processing", Wiley India Private Limited, New Delhi, India, 2015.
[8]. William K. Pratt, "Digital Image Processing", 4th Edition, Wiley India Private Limited, New Delhi, India, 2016.
[9]. Bernd Jähne, "Digital Image Processing", 6th Edition, Springer-Verlag India Private Limited, New Delhi, India, 2017.
[10]. S. Avidan, and A. Shamir, "Seam carving for content-aware image resizing," ACM Trans. on Graphics (Proc. of SIGGRAPH) 26(3), 10, 2016.