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A Visual Attention Based Improved Seam Carving For Content Aware Image Rescaling

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ABSTRACT: *Content-aware image resizing is a kind of new and effective approach for image resizing, which preserves image content well and does not cause obvious distortion when changing the aspect ratio of images. Saliency detection plays important roles in many image processing applications, such as regions of interest extraction and image resizing. Effective resizing of images should not only use geometric constraints, but consider the image content as well. The basic idea beyond these algorithms is the removal of vertical and/or horizontal paths of pixels (i.e., seams) containing low salient information. In The proposed system, present a method which exploits the gradient vector flow (GVF) of the image to establish the paths to be considered during the resizing. The relevance of each GVF path is straightforward derived from an energy map related to the magnitude of the GVF associated to the image to be resized. To make more relevant, the visual content of the images during the content-aware resizing, also propose to select the generated GVF paths based on their visual saliency properties and a blending method in order to obtain better visual results in joining adjacent image regions after seams removal. The depth of the scene will be considered to make more visually consistent the resized images. In this way, visually important image regions are better preserved in the final resized image. The proposed technique has been tested, both qualitatively and quantitatively, by considering a representative data set of images labeled with corresponding salient objects (i.e., ground-truth maps). Experimental results demonstrate that our method preserves crucial salient regions better than other state-of-the-art algorithms.*

INDEX TERMS- *Content aware image resizing, image retargeting, visual saliency, gradient vector flow.*

I. INTRODUCTION

The extensive use of display devices with different resolution (e.g., on pc, tablet, Smartphone, etc.) increases the demand of image resizing techniques which consider the visual content during the scaling process. Standard resizing techniques considering only geometric constraints, such as scaling, can be used only to change the image size (width and height) of a fixed percentage with respect to the original one. Scaling does not take into account the visual importance of pixels during image resizing (i.e., a resizing with respect to only one dimension introduces artifacts and distortions). Other standard operations in which outer parts of an image are removed (e.g., cropping), could produce images with loss of salient information (e.g., removal of objects or part of them). In the last years, several techniques for content-aware image resizing (or content-based visual retargeting) have been proposed. The main aim of a content-aware image resizing is the preservation of relevant visual information into the resized image. Intuitively, the goal is to remove unnoticeable paths of pixels that blend well with their surroundings, and retain the salient pixels which are important to generate the needed visual stimuli useful to correctly perceive the visual content. The algorithm should avoid distortion and changes of perspective of the image. Moreover, they should preserve edges, important textured areas belonging to the objects, size of the objects, and relevant details of the scene. The Seam Carving, proposed by Avidan et al. in, is probably the most popular content-aware resizing approach. Such a technique reduces the image by removing connected path of pixels (called seams) having low-energy in the map related to the image to be resized. The authors of compared different strategies to compute the energy map to be considered during the resizing process (e.g., the entropy energy computed for each pixel into a fixed window, the magnitude of the gradient computed on each pixel, a saliency measure of each pixel computed as in, etc.).

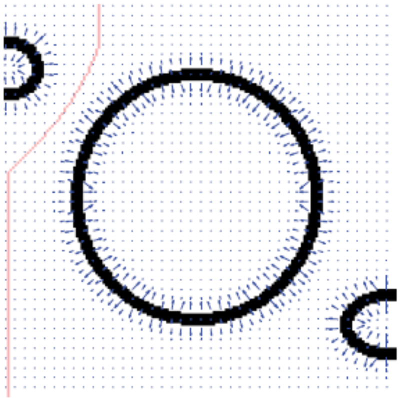

Fig 1 Input image with ITS corresponding GVF field over imposed. GVF values are higher in correspondence of the edge information. The seam derived by the proposed resizing approach is shown in red. The gradient vector field forces the seams fall from main contours of the object.

An interesting and powerful extension of standard resizing operators (i.e., scaling, cropping, etc.) and content-aware based algorithms (i.e., seam carving) can be obtained by their combination, as proposed by Rubinstein et al. in. They propose a technique able to search for the optimal sequence of operators to be applied at each step of the resizing to get better results in terms of visual quality of the final reduced image. On the other hand, the computational complexity increases due to the use of different operators. Among others, patch-based methods have been also proposed for image retargeting or summarization. In particular, Cho et al. suggested an algorithm to find an arrangement of patches of the original image that well fit in the resized image, whereas Pritch et al. introduced a method to find the best Shift-Map which defines the pixel displacement useful to produce the output image. Wu et al. propose a resizing method exploiting also high level semantic features such as symmetry. Specifically, their approach resizes symmetry regions by summarization and the remaining ones by warping. In this case the resizing method considers non-homogeneous warps to concentrate the resizing distortions in regions with low saliency information. To this aim, the resizing problem is formulated as a quadratic minimization problem and different metrics are considered to measure the image distortion. Gallea et al. proposed a fast method for image retargeting based on the solution of a linear system. This model aims to find shift values for each line (row/column) preserving the distance among the relevant ones. The linearity of the considered model allows them to elaborate even large images in reasonable computational time.

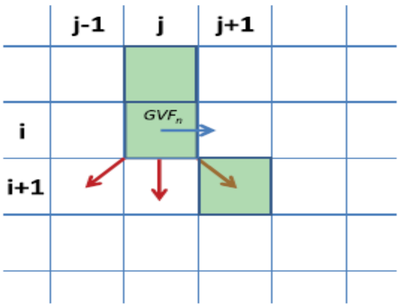

Fig 2 An example of seam generation among the three possible directions (in red) the one with angle closest to the GVF orientations (in blue) is chosen.

This paper introduces a novel algorithm for content aware image resizing. The technique exploits the properties of Gradient Vector Flow (GVF) to properly detect the seams to be removed, without introducing artifacts in the resized image. Specifically, GVF generates a vector field useful to preserve objects by enhancing edges information during the generation of the possible paths to be removed. The vector field produced by GVF is also coupled with a visual saliency map in order to refine the final selection of the paths to be removed. The proposed approach has been tested and compared, both qualitatively and quantitatively, with respect to state-of-the-art approaches on a representative dataset. Experimental results confirm the effectiveness of the proposed approach in terms of preservation of salient regions.

II. PROPOSED METHOD

One of the main issues of the content aware image resizing is the preservation of the salient information contained in the image under analysis. To this aim, our algorithm makes use of the properties of the Gradient Vector Flow (GVF).GVF is a dense force field useful to solve the classical problems that affect snakes: sensitivity to initialization and poor convergence to boundary concavity. Starting from the gradient of an image, this field is computed through diffusion equations. Formally, GVF is the field **F** of vectors **v** = [u, v] that minimizes the energy function

$$E = \iint \mu(u_x^2 + u_y^2 + v_x^2 + v_y^2) + |\nabla f|^2 |v - \nabla f|^2 dxdy \quad (1)$$

Where the subscripts represent partial derivatives along x and y axes respectively, μ is a regularization parameter, and |∇ f | is the gradient computed from the intensity of the input image. Due to the above formulation, GVF field values are close to |∇ f | values in those areas where this quantity is large (energy E, to be minimized, is dominated by $|\nabla f|^2|\mathbf{v} - \nabla f|^2$), and are slow-varying in homogeneous regions (the energy E is dominated by the sum of the squares of the partial derivatives of GVF field). Hence, GVF is stronger close to the edges of Objects within the image. An example of GVF field is shown in Fig. GVF values are higher in correspondence of the edges information. The seam derived by the proposed resizing approach is shown in red. The gradient vector field forces the seams far from main contours of the objects. Its exploits this vector field to effectively build the set of pixel paths (i.e., the seams) to be considered as candidate in the removal process. The relevance of each GVF path can be straight forward derived from the energy map obtained by the GVF magnitude associated to the image under consideration.

Let I be an image with H rows and W columns to be resized with respect to the width, and 0 < N < W the number of seams to be removed. First the GVF and its normalized version GV Fn (i.e., each vector with norm one) are computed from the input image I considering the luminance channel (i.e., Compute GVF). Several seams {s1, s2. . . sK } are then built starting from the top of the image making use of the directions of the already computed GV Fn (i.e., Seams Computation). The algorithm devoted to the generation of the seam has been designed to exploit the properties of the GVF field. Specifically, this field preserves the strong edges and propagates the information related to their presence also in the neighboring pixels. Starting then from the top of the image and following the GVF field direction a seam avoiding as much as possible main edges is built. It is worth noting that the directions suggested by GVFn cannot be always followed. Specifically, considering a generic pixel p of coordinates (i, j) belonging to a seam sk , the next element of sk has to be chosen among (i + 1, j −1), (i + 1, j), (i + 1, j + 1). These pixels can be related to the following unit vectors (−√2/2, −√2/2), (0, 1), (√2/2,−√2/2).Among the aforementioned unit vectors associated to a specific direction, the one making the smallest angle with GV Fn(i, j) is hence considered during the seam generation
To this aim, a simple dot product between GV Fn(i, j) and the three considered unit vectors is employed. To sum up a generic seam sk is built repeating H − 1 times the aforementioned direction selection algorithm starting from a pixel p with coordinates (1,w) at the top of the image (w = 1, ,W at the first iteration of the resizing).

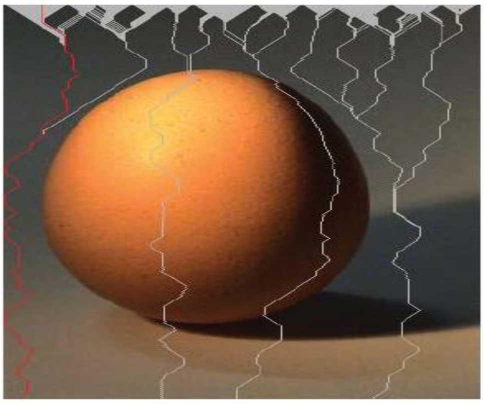

Fig 3 The seams to be removed selected considering the related path is shown in red.

The proposed algorithm works similarly for the resizing with respect to the height. After computing the set of candidate seams {s1, s2. . . sK },a cost is associated to each seam by considering the sum of the GVF magnitude |GV F| of the pixels belonging to the seam. Specifically the cost ck of a seam sk is computed as follows

$$C_k = \sum_{(i,j)\in S_k} |GVF\ (i,j)| \qquad (2)$$

The seam with the lower cost ck is hence removed from the image at each iteration (i.e., Remove Seam). The GVF map is then updated and a new iteration of the seam removal algorithm is performed for each seam to be removed. It is worth noting that the core of the proposed resizing approach is related to the method adopted to select the seams (i.e., Seams Computation). Indeed, the seam selection method has been designed to exploit the properties of the GVF in order to maintain the strong edges of the images and propagates their contributions also in their neighboring creating then a repulsive field. On the contrary, classic Seam Carving approaches do not propagate the information of a strong edge into the close pixels. Moreover, GVF combines the contribution of several edges in a smooth way. Differently than Seam Carving], the proposed approach, due to the repulsive field that propagates the information about the presence of an edge also in its Neighboring, can perform a simple seam selection guided by the GVF field without considering all the possible paths. All the possible paths generated at iteration t are shown in gray and the best one in red. As can be easily seen, only a limited number of paths are actually considered and, usually, they do not cross the salient region.

III. SALIENCY BASED SELECTION OF GVF PATHS

The visual salience (or visual saliency) refers to the properties of the visual stimuli which are exploited by the human visual system in the tasks of visual attention and rapid scene analysis. The automatic detection of salient regions in images can be used in a broad scope of computer vision applications such as image segmentation, content-based image retrieval, object detection and recognition.

Several saliency estimation methods have been proposed in literature. Some of them, such as the algorithm proposed by Itti et al., originate from the biologically plausible visual architecture proposed by Koch and Ullman. Others methods, such as the one presented by Achanta et al. in and by Hou et al. in, are purely computational and do not make any assumption on biological architecture. Finally, techniques based on combining both paradigms, biological and computational, have also been published, as in the work of Harel et al. All previously mentioned approaches estimate the visual importance of image pixels starting from information extracted in the uncompressed domain. Since most images (e.g., over internet) are stored in the compressed domain of joint photographic expert group (JPEG), Fang et al. Have proposed a method to extract saliency directly in the JPEG domain by exploiting information of intensity, color, and texture encoded by the discrete cosine transform (DCT) coefficients on each 8x8 block.

Visual saliency estimation algorithms have straightforward application in content based visual retargeting. Indeed, all the state-of-the-art retargeting algorithms detect the paths to be removed (i.e., the seams) taking into account of an energy map which encodes the importance of each pixel in terms of content. A successful seam carving algorithm should ensure that the most important image regions pointed out by the energy map should not be removed. The algorithm we presented in Section II makes use of the magnitude of the GVF as energy map to drive the selection of the seams to be removed. Despite this information is useful to take care of the saliency of the edges, it does not consider other saliency information. In Achanta et al. A visual saliency map able to uniformly highlight salient regions with well-defined boundaries has been used for content aware image resizing purpose; the classic seam carving algorithm proposed by Avidan et al. Has been employed by replacing the energy map computed using the L1-norm of the image intensity gradient, with the saliency map computed. Results presented emphasized the fact that by using the visual saliency better performances, with respect to the state-of-theart methods, are achieved. This strongly motivated us to couple the proposed GVF based approach with saliency information for retargeting purpose.

In this paper propose to use visual saliency only for the selection of seams to be removed after that these paths are generated by exploiting the gradient vector flow as detailed in previous section. In this way we are able to combine different kinds of saliency information; the one related to the edges given by the GVF and the one related to the saliency objects within the image encoded by the saliency map. In our experiments we used the saliency map estimator proposed by Achanta et al. To include visual saliency information, first generate the seams exploiting the GVF, and then perform the selection based on saliency. The cost function is given by,

$$\mathrm{C_k} = \sum_{(\mathrm{i,j})\in \mathrm{S_k}} \mathrm{Saliency(i,j)} \qquad (3)$$

Where Saliency(i, j) is the value of visual saliency of the pixel (i, j) computed.

IV. EXPERIMENTAL RESULTS

The performance of a content-aware image resizing algorithm strongly depends on the adopted energy map which captures the salient regions of an image. As described in previous sections, we propose to use GVF to build the seams during the resizing. The selection of the seams to be removed is then driven by GVF magnitude or by the saliency map. In order to evaluate the results of our basic approach and do not consider saliency information, we have compared it with respect to the classic Seam Carving algorithm proposed by Avidan et al, and the approach recently proposed by Gallea et al. The approach has been re-implemented, whereas the original code of the method has been provided by the authors.

While proposes a local-based approach which exploits the gradient of the image to select the seams to be removed, the approach is a global-based approach in which an objective function is considered to solve an optimization problem. In the product of the gradient of the image and the saliency map proposed by Itti et al. is taken into account as energy map during the resizing. Moreover, to underline the contribution of coupling GVF path extraction with saliency based selection compared the proposed saliency based selection approach with respect to the other systems.

In order to objectively assess the performances of the aforementioned methods compared the different approaches on the dataset used for saliency detection. For each image I of the dataset, the ground-truth map denotes which pixels of the image are important in term of saliency. In Fig. 5.1 are shown respectively an image considered in the experiments and its corresponding ground-truth map. Since the aim of content-aware image resizing is to preserve salient regions, we used the following cost function in order to objectively evaluate the performances

The cost can be used to fairly compare the performances of the different algorithms at varying of the scale factor. A lower cost value indicates better performances.

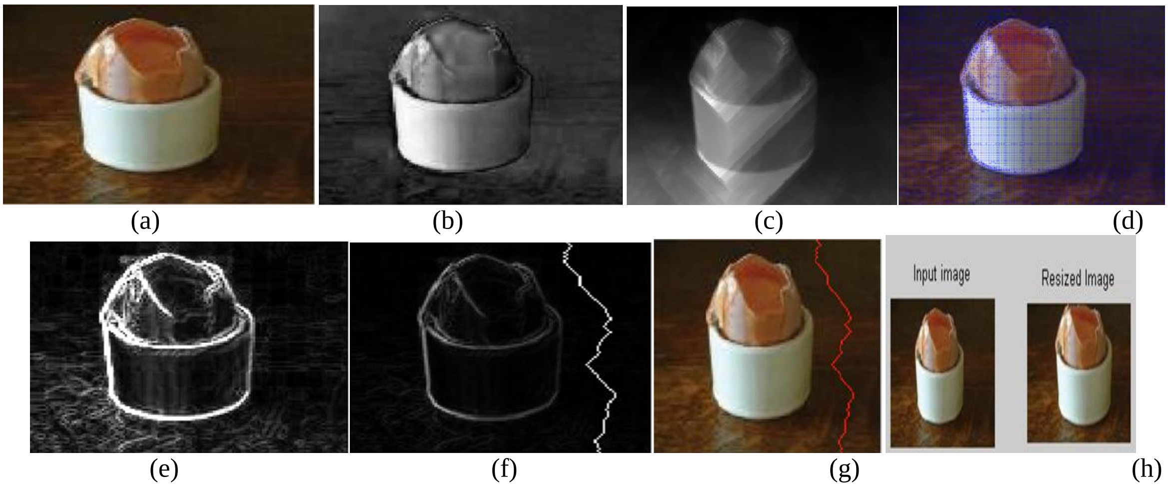

Fig 4. (a) Original image, (b) Image in lab color space, (c) Saliency map, (d) Gradient vector flow map, (e) Ground truth mask, (f) Seam generation, (g) The maps of the removed seam showed in red, (h) Resized image.

$$Cost(I, A, \lambda, d) = \sum_{p \in \Psi_{A,\lambda}(I)} G_I(p) \qquad (4)$$

Where $\psi_{A,\lambda}(I)$ is the final set of pixels removed by employing the algorithm A during the resizing of the image I of a scale factor $\lambda \in \{95\%, 90\%, 85\%, 80\%, 75\%, 70\%\}$ with respect to the maximum dimension of the image (as defined by equation (4)), and $G_I(p)$ indicates the importance of there moved pixel p in the image I.

$$d = \underset{\hat{d} \in \{width, height\}}{\arg\max}\ Size(I, \hat{d}) \qquad (5)$$

This cost can be used to fairly compare the performances of the different algorithms at varying of the scale factor. A lower cost value indicates better performances (i.e., more salient pixels are preserved in the resizing). We have measured the performances of the different algorithms on the aforementioned dataset at varying of the scale factor.

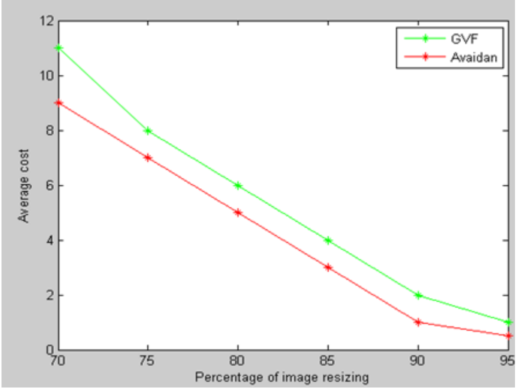

Fig 5 cost performance

The final results are obtained by averaging the results of all the executions for a specific scale factor λ.

In Fig. 5 are reported the results obtained by the three different algorithms which exploit the magnitude of the image gradient to select seams to be removed during the resizing: our Algorithm, the one proposed by Gallea et al. and the original Seam Carving algorithm proposed by Avidan et al. The results are shown at varying of the percentage of the resizing. To visually assess the results obtained with the five compared algorithms, some visual results obtained by resizing images with a scale factor of 70% with respect to their original dimension (width or height)A visual comparison reveals that the proposed approach with saliency based selection of GVF path better preserves the main salient regions (i.e., the areas with objects). The experimental results demonstrate the effectiveness of the proposal which reduces the computational cost during the resizing by maintaining almost the same performances in terms of saliency preservation.

V. CONCLUSION

The proposed novel content-aware image resizing algorithm which exploits information extracted through Gradient Vector Flow to establish the paths to be considered during the resizing of an image. The proposed GVF based approach is enriched with saliency information to achieve better results. The proposed solution has been compared with respect to state-of-the-art algorithms on a representative dataset achieving at least comparable visual results, and outperforming with good margins existent strategies in terms of preservation of salient regions. Some visual result obtained by resizing images with a scale factor of 70% with respect to their original dimension(width and height).the proposed method based just on GVF information achieves the best results demonstrating that the process of building seams by exploiting GVF more effectively preserves salient areas and hence removes less crucial pixels. A visual comparison reveals that the proposed approach with saliency based selection of GVF paths better preserve the main salient regions (areas with object) .Future works can be devoted to include a blending method in order to obtain better visual results in joining adjacent image regions after seam removal.

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