OICR: Classification and Evaluation of Image Content-Aware Retargeting Techniques

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***Abstract*—With the development of portable digital devices equipped with different resolutions and sizes, the issue of image retargeting has become a subject of active research in the field of image processing. Recently, salient research efforts have been done in fields of image content-aware resizing. A review of the previously proposed techniques indicates that there are diverse techniques for resizing images and eliminating distortions caused by different resizing scenarios. A wide range of image content-aware retargeting issues and a wide range of techniques make it difficult to compare and accurately assess the techniques. Accordingly, this article proposes an opinion-based framework used an image content-aware retargeting (OICR) techniques to explore the techniques more precisely. In the proposed framework OICR, at first the techniques are classified based on the used opinion. Then the techniques are evaluated based on some proposed appropriate functional criteria. The use of the proposed framework is useful for the suitable selection of image content-aware retargeting techniques, and it provides a more accurate comparison between techniques and improves the efficiency of methods.**

***Keywords*—Image retargeting, OICR, saliency detection, image content-aware resizing.**

I. Introduction

According to recent advances in the field of digital portable devices and displays with different resolutions and aspect ratios, the importance of displaying images efficiently on screens has increased compared to the past. Images recorded with digital cameras usually have different resolutions and different aspect ratios for compatibility with any screen. These images require a change in resolution [1, 2]. General image resizing techniques (e.g., uniform scaling and cropping) only consider the limitations of display space and do not pay any attention to the image content, therefore they have poor performance in the resizing image, and in most cases they lead to the elimination or distortion of important information of input image. To meet the challenges associated with traditional techniques, image content-aware retargeting has been raised in recent years [3,4]. The main effort of the retargeting technique is to offer an outline for image resizing with the aim of reducing distortions of features and important image information during image resize [5,6].

Comparing and accurate assessment of image content-aware retargeting issue is difficult due to its wide range and diverse approaches. Hence, this paper proposed a framework to introduce image retargeting techniques based on used opinion. In the proposed framework, in addition to identifying and introducing techniques in a systematic form, the techniques are evaluated by some proposed functional criteria. Using the proposed framework helps in the appropriate selection of image content-aware retargeting techniques, given their diversity, the proposed framework provides a more accurate comparison between techniques and it improves the efficiency of techniques.

The rest of the paper is organized as follows: In Section II, the problem definition is presented for the subject of image content-aware retargeting (ICR). Then, the proposed framework is represented in Section III. In Section IV, the ICR techniques are evaluated in the proposed classification framework based on functional criteria. The final section presents the conclusion and future works.

II. Image Content-Aware Retargeting

The image content-aware retargeting issue was defined by Vaquero et.al. [6] as: given an input image I with the size of $m * n$ and a new size of $\acute{m} * \acute{n}$, the goal is generating a new image $\acute{I}$ by size of $\acute{m} * \acute{n}$ that will represent the input image well. According to Avidan et.al. [7], the main goal of image content-aware retargeting issues are:

- Preserving the important component of the input image in the resized image.
- Reducing the visual distortions in the resized image.
- Preserving the important structure of input image.

Most image retargeting techniques follow the same process to achieve the goals. Fig. 1 shows the block diagram of the image content-aware retargeting process. This process includes two main stages. The saliency map is calculated to show the visual saliency of each pixel of the image in the first stage. The input image is retargeted into the new size by content-aware resizing operators given by the saliency map and restrictions in the second stage.

III. OICR: The Proposed Framework

This section proposes a framework for more exact study of ICR techniques called OICR. The OICR is organized based on ahead opinion in ICR articles, which is shown in Fig. 2.

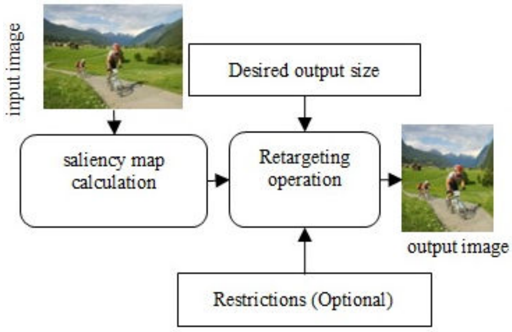

Fig. 1. Image content-aware retargeting process

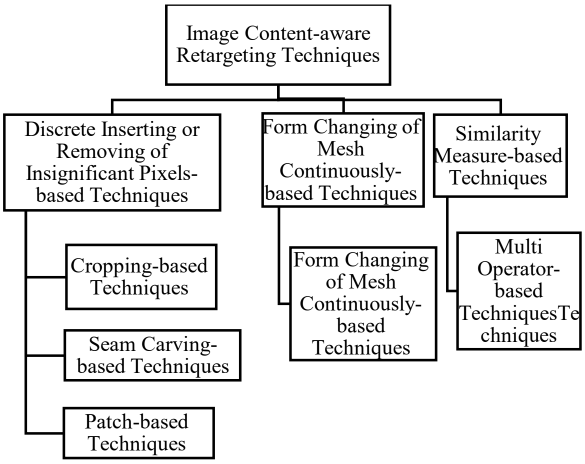

Fig. 2. The proposed OICR framework

A. Discrete Inserting or Removing of Insignificant Pixel-Based Techniques

The main goal of this class is resizing the input image by inserting or removing insignificant areas. Actually, this class of techniques tries to prevent from distortion of important components of the image by inserting or removing insignificant areas. This class is divided into three subclass: Cropping-based Techniques, Seam Carving-based Techniques, and Patch-based Techniques. Below, each sub class is described briefly.

1) Cropping-Based Techniques

In the techniques of this subclass, the search process is performed based on visual salience measures such as face detection to find an optimum cropping window containing important image components. These techniques prevented the distortion of important image components. Through the literature review in this field, we can insinuate some of the challenges in this class. For example, the complete removal of input image areas that are out of the cropping window is one of the main challenges in this subclass. Also, there are no satisfying results for images that contain several dispersed important components in techniques of this class [8,9,10].

2) Seam Carving-Based Techniques

This subclass is considered to be a very effective technique for resizing of the content-aware image. The main opinion of these techniques is resizing the image in a specific direction by inserting or removing homogenous one-dimensional seams. A seam is a path that includes eight horizontal or vertical connections of pixels with the least amount of energy. Seams are defined so that a uniform path continues and includes only one pixel in each row or column [7]. The vertical seam was obtained for the input image (I) of size n*m as follows:

$$S^x = \{S_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n, s.t. \forall i, |x(i) - x(i-1)| \le 1 \qquad (1)$$

where x is the mapping $x : [1,...,n] \to [1,...,m]$, $(x(i), i)$ is the pixel position in *i* row and *x(i)* a column. There are two main steps in finding a seam with the least amount of energy. In one step, the cumulative energy map of *M* is computed. Then, in the second step, the optimum seam was fined by dynamic programming. The vertical energy map is obtained as follows:

$$M(i,j) = e(I_{i,j}) + \min\begin{cases} M(i-1, j-1) \\ M(i-1, j) \\ M(i-1, j+1) \end{cases} \quad \forall 1 \le j \le m, 2 \le i \le n \qquad (2)$$

where $e(I_{i,j})$ is the amount of importance for each pixel of the image in *i* row and *j* column. The image width was resized to the desired size by removing and/or inserting vertical optimum seams repeatedly (horizontal optimum seams were also achieved by similarity) [7]. An example of seam carving techniques [11] is shown in Fig. 3.

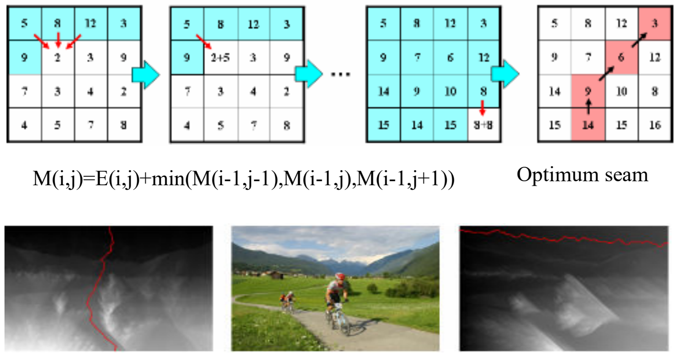

Fig. 3. Example of seam carving techniques [11]

3) Patch-Based Techniques

In this class of techniques, the input image is considered as a set of small patches and resizing is performed by reorganizing these patches inside the pallet with the desired size [8]. Although this subclass can keep the general content of the image, but there are drawbacks such as high computational costs and inability to keep the local structure of objects in this sub class.

B. Form Changing of Mesh Continuously-Based Techniques

The main opinion of techniques in this class is displaying the input image and local form changing of polygons by using an uncertain warping function to create a final resizing image. These techniques have been tried to keep both important and insignificant areas in final image and achieve a suitable balance between the final image and distortions caused by resizing.

1) Warping-Based Techniques

The image content was distorted based on the importance of each nonlinear area. The major aim of the subclass is to further distort the insignificant areas and reduce visual distortions of important components of the image. To achieve this goal, most warping-based techniques were performed in three stages an example of which is shown in Fig. 4.

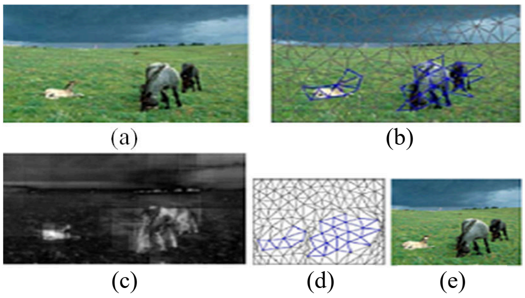

Fig. 4. General framework of warping-based techniques

At this stage, the polygon form-changing function is defined to determine the amount of warping in each polygon, and it is shown as follows:

$$\sum_{i} S(V_i) \sum_{j s.t. \{i,j\}\in E} \| (V'_j - V'_i) - S_i(V_j - V_i) \|^2 \tag{3}$$

where V and V' are the primary and final positions of vertices in each iteration, respectively. Also, $S(V_i)$ is the importance amount of each vertex due to the importance map of S, which is computed by periodicity optimization.

Example of line warping limitation is displayed in Fig. 5.

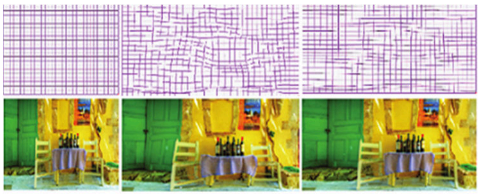

Fig. 5. Applying of line warping limitation [12]

As can be seen in Fig. 5, defined limitations on vertices and edges of polygons made the final image with the least distortion.

C. Similarity Measure-Based Techniques

The main goal of the third class is to select the best image among all the resized images as the final image that it has most similarity with the input image. Many of the techniques in this class have been used in combination with several operators for the improvement of image resizing.

1) Multi-Operator-Based Techniques

The literature review demonstrated that there are no content-aware resizing operators that provide satisfying results for all image positions and sizes. Therefore, in many recent works the use of multi-operator techniques was proposed for the presentation of better results. For example, in [12], to resize the input image to the desired size, a seam carving operator and a uniform scaling technique were integrated. It should be noted that the ordering of operators employing will lead to different results. Then, a patch-based bi-directional similarity measure was used to compute the degree of similarity between input image and obtained image from each combination and then to select the best combination than the other combinations. The similarity between the input and output images (S and T) is computed by bi-directional warping measure as follows:

$$BDW(S,T) = \frac{1}{N_s}\sum_{i=1}^{h} A-DTW(S_i,T_i) + \frac{1}{N_T}\sum_{i=1}^{h} A-DTW(T_i,S_i) \tag{4}$$

where h is the height of images S and T, S_i and T_i is i row in S and T images respectively. After calculating similarity for all possible positions, the image that has the greatest similarity with the input image was chosen as a result [21-23]. In the following, example of techniques performed on the input image is shown in Fig. 6.

Fig. 6. Result of comparison between different image content-aware retargeting ttechniques

IV. Evaluation of OICR Framework

This section consists of two main parts: proposed functional measures and results.

A. Proposed Functional Measures

The proposed measures for evaluation are listed below:

- **Opinion**: It is used as a general idea in proposed technique for ICR [19].
- **Advantage**: It is existing strengths and benefits in each class of techniques.
- **Drawback**: These are the disadvantages in the presented technique that may lead to reduced efficiency.
- **Accuracy**: It is the precision level of the technique used for ICR, measured by three values: high, medium and low [20].
- **Computational cost**: It is the total cost of computations in ICR process adopted as high, medium and low [21, 22].

B. Results

In this section, evaluation results are summarized in Table I. As can be seen from Table I, there are the highest and lowest accuracies in the multi-operator-based techniques, and cropping-based techniques respectively. Generally, the accuracy of multi-operator-based techniques is higher than other techniques due to using the benefits of multiple operators simultaneously. Actually, the use of multi-operator has been effective to improve the efficiency of the content-aware image retargeting techniques. Also, the use of a large amount of computation in this class will lead to higher computational costs than classes, since there is a step evaluation of similarity measures in the techniques of this class. Many of the cropping-based techniques have employed a conventional crop for image content-aware retargeting. Hence, the computational cost of techniques in this class is lower than in other classes. The accuracy of seam carving-based techniques is high. Its reason can be the lack of resizing in important image components.

V. CONCLUSION AND FUTURE WORKS

In this paper, a used opinion-based framework was proposed for the classification and evaluation of image content-aware retargeting techniques, called OICR. According to the proposed framework, image content-aware retargeting techniques were first identified, and then classified into three general classes: discrete inserting or removing of insignificant pixel-based techniques, form changing of mesh continuously-based techniques and similarity measure-based techniques. Finally, each class of techniques was evaluated based on some proposed measures. As a result, it can be said that the use of the proposed framework, OICR, can help in the suitable selection of image content-aware retargeting techniques, providing an appropriate context to compare techniques and improve them.

The presentation of a hybrid technique can be introduced as a future study.

Table I: Evaluation results of image content-aware retargeting techniques in the proposed framework

Techniques		Measures				
		Opinion	**Advantage**	**Drawback**	**Accuracy**	**Computational cost**
Discrete Inserting or Removing of Insignificant Pixel-Based Techniques	Cropping-Based	Conventional cropping [8]	➢Keeping main structure of image ➢Final image without distortion	➢Inefficiencies for images that include more than one important component	Low	Low
	Seam Carving-Based	Main seam carving [7]; Corrected seam carving [13]; Indirect seam carving [12,14]	➢Keeping local structure of image ➢No resizing in important components of image	➢Inability in keeping the main structure of image ➢Inefficiencies for condensing images	High	Medium
	Patch-Based	bi-directional similarity [16]; Transition map [15]	➢Keeping general structure of image ➢Existence of the least distortion in the final image	➢Inability in keeping local structure of image ➢High computational cost	Medium	High
Form Changing of Mesh Continuously-Based Techniques	Warping-Based	Warping based on a triangular mesh [17]; similarity conversion [18]	➢Distortions distribution in different directions of image ➢Keeping main structure of image	➢Inability in keeping relative proportion of components	Medium	High
Similarity Measure-Based Techniques	Multi-Operator-Based	Integrated of seam carving, scaling and warping operators [18]; Integrated of seam carving and scaling [12,14]	➢Existence of the least distortion in the final image ➢Using the appropriate aspects of each of the operators	➢Inability to overcome the intrinsic defect of operators	High	High

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