Resizing Images Using Seam Carving with Graphs and Hough Transform

Image Processing project

ALI Mohamed, OCHOA Eduardo, VALENCIA Liliana

January 11, 2018

Abstract

Resizing images effectively can be a challenging task. Different techniques can be used in order to achieve good results from the basicm considering tradition approaches as cropping and scaling to most content aware technique as seam carving. We present an algorithm that perform reduction of the images using seam carving with graphs in order to find the shortest path and the application of Hough transform to protect lines and the distortion in the image.

1 Introduction

Advances in the displaying images devices represent a challenge in the image size and resolution. Depending of the device, images must be resize to fit in a particular space. This process is called image resizing or image retargeting and its basic idea is find the best map of an input image that preserve the salience regions and shrinks or expand the images using the less important regions in order to give the best output image so that few changes can be perceive.

Many techniques have been propose to perform images resizing. They can be *geometric constrains* as cropping or *content-aware*. The content-aware techniques are the most studied because they take care of the content which depending on the image can be a challenge since the determination of the important regions is very subjective. Some content aware methods are: content-aware cropping, content-aware scaling, seam carving, patched-based method, image warping. Every method has its own advantages and disadvantages but all of them attempt to give the best visual result as possible.

Seam Carving, is the main approach of this report. The general idea of the method is to decrease the image size, one pixel at the time by removing a seam of minimum importance. As advantage seam carving has the possibility of involve several visual saliency measures to define the energy of the image and interact with the user to guide the process . As a drawback, with simple row/column seam removal it can excessively carve less important parts of the image. To improve seam carving result, some techniques as Hough transform can be apply in order to correct the distortion in straight lines or regular patterns.

In this report, we propose a method to resize images applying seam carving using graphs and the integration of line detection with Hugh transform to preserve lines deformation.

2 Problem Description

The image resizing problem can be described as an input image I with a size mxn that should be transform in an new I' image with a m'xn' size than must be as close as possible to the original image.

Resizing an image can involve loss of information or image deformation when it is perform with traditional methods as cropping or scaling [1] as is shown in Figure 1. These methods are mostly interest in the geometric constrains but not in the image content.

In order to solve these issue, different techniques that consider the content of the image, preserving important regions and minimize the distortion, is required. The *content-aware retargeting* methods can achieve these objectives. They can be classified in discrete and continuous. Continuous solutions optimize a mapping (warping) from the source media size to some target size limited on its important regions and admissible deformations

Figure 1: *An example of retargeting. From left to right: original image, resized using seam carving, scaling, and cropping*

[2], and its principal advantage is that allows controlling the smoothness of the retargeting operator mainly because instead of remove image content, this approach redistributes image density. Discrete methods increase or decrease the total numbers of pixels of the image trying to preserve the most important media content. As is stated in [3] this approach is specially good in resizing images rich in textures content but it is known to have some smoothness artifacts.

Most of the methods have three objectives [4] described as:

1. Preserving the important content of the original image
2. Limiting visual artifacts in the resulting media
3. Preserving internal structures of the original media

Seam Carving belong to the discrete methods and is very large used to resize images. It is based on the detection of the minimum energy seams through the computation of the energy function of the image and manipulate it with this information.

A seam (Figure 2) can be defined as a path of 8 connected pixels from top to bottom or from left to right each pixel in one row or columns depending on the selected direction. As is defined in [5], a valid vertical seam $s = \{x(i), i\}_{i=1}^{H}$ in an image I with height H must fulfill two conditions: first, the seam consists of one and only one pixel in each row, and second the horizontal distance between two adjacent seam pixels $|x(i) - x(i-1)|$ is not allowed to exceed a threshold of T. These conditions lead to the following definition of a vertical seam:

$$s = \{x(i)\}_{i=1}^{H} = \{(x(i), i)\}_{i=1}^{H}, s.t, .\forall_i : |x(i) - x(i-1)| \leqslant T$$

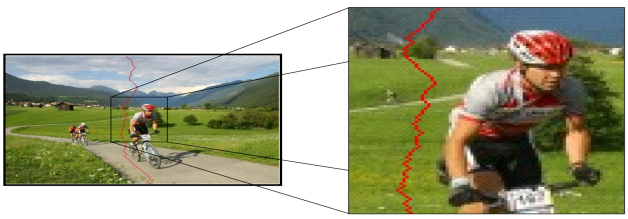


Figure 2: *Seam application on an image.*[6]

Where T is equal to 1.

To compute the energy map, there are different methods, to mention some of them:

- Gradient magnitude: compute the energy using gradient operator as sobel, prewitt, laplacian or robert. In this case the energy function is defined as:

$$e(x,y) = \left|\frac{\partial I}{\partial x}\right| + \left|\frac{\partial I}{\partial y}\right|$$

- Histogram of Gradients (HoG): this method takes the histogram of the oriented gradient at every pixel.
- Entropy: defined as
$$H = -\sum p_k log_2(p_k)$$
Where k is the number of gray-levels and p_k is the probability associated to the gray-level k.

As is stated in [7], no single energy function performs well across a full set of different images but in general they all accommodate a similar range for resizing.They vary in the rate at which they introduce visual artifacts and the parts of the image they affect.

The basic algorithm to find the optimal seam is described as: determine the cumulative energy map in order to detect the optimal seam. The pixel with the lowest value in the cumulative map, in the last row or column, depending of the direction, is picked and backtracked to get the optimal seam. Now, with the optimal seam found, it can be manipulate to have the desire result: for increase the size of the image the optimal seam can be duplicate, for reducing the size the optimal seam can be remove.

3 Improved Seam Carving

Seam Carving belongs to the pixel removing category. By removing paths of low energy pixels it is possible to achieve the resizing of an image. Even when seam carving was proposed as a content aware resizing method it works only for a very small dataset[8]. This approach will work perfectly for images in which large portions are occupied by the background and in images where the energy of the less interested parts is constant and the algorithm is able to remove this parts without damaging the regions of interest.

Furthermore, seam carving methods can failed and have errors when an image includes regular patterns or straight lines. In this type of cases when the process of removing seams makes two of them pass right next to each other over a line the whole line is displaced and creates artifacts in the scene, as shown in the Figure 3.

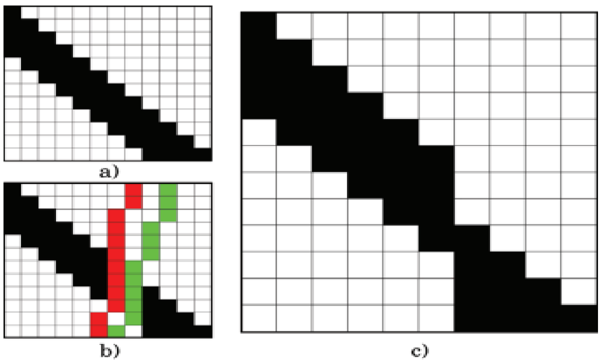


Figure 3: *Line getting distorted by the coincidence of two seams that are being removing next to each other*

By applying graphs to find the shortest path in an image and perform the seam carving algorithm and use the *canny edge detection method* combined with *Hough transform* it is possible to protect lines in the image and also help restricting visual distortions in the image.

3.1 Seam carving using graphs

The first thing to do is to make an implementation of the seam algorithm. As it is said the first thing is to take an image (whichever it is) and make a content aware re-sizing of it. For this there are a lot of cases of content aware techniques that help maintain the coherence on the image. It is considered here images with a good quantity of straight lines that can be deformed by a re-sizing of the image. In the implementation we first compute the energy map of an image by calculating the entropy of the image in a 3x3 window for each pixel. In Figure 5 we can see the energy map of a tennis court image using the entropy method.

Then from the energy map it is possible to calculate in vertical or horizontal direction the least energy path, this kind of problems (of finding the shortest path) have been of interest in many applications and have been

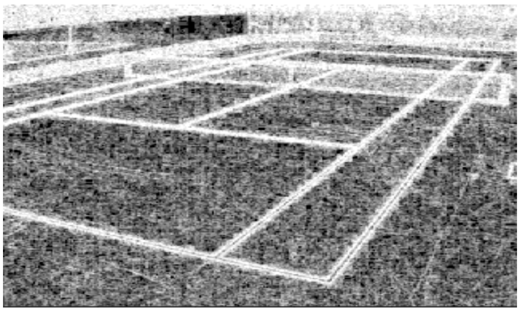


Figure 4: *Energy map obtained by applying the entropy in a 3x3 neighborhood window on an image*

well developed by the graph theory, which is the approach used. Graphs are mathematical structures that are used to model objects in which some pair of them are in some sense related. A graph is a pair of sets (V,E), where V is the set of vertices and E is the set of edges, formed by pairs of vertices [9]. The graph theory is applied in a lot of areas of science and processes to represent many problems.

For the calculation of each seam in our image we search for the shortest path of pixels that have the less cost in the horizontal direction, that means that the algorithm goes through every column of the image until reaching the other side and obtaining the coordinates of the pixel that represent the less cost path. If this is want to be done in the vertical direction the image just have to be rotated and then perform the algorithm.

3.2 Detection of straight lines using Hough Transform

Parallel to the seam carving algorithm implemented, it is of particularly interesting the protection of the image when it has a really considerable quantity of straight lines in the scene that can deform the image or create artifacts in it when the re-sizing is done. This algorithm follows the basic steps for the lines detection and uses the Hough transform algorithm to find the corresponding pixel line's coordinates.

First, *Canny edge detection* is used to detect the edges of the input image. A Gauss mask of size 2 is then used in the algorithm to take care of noise in the image, and a thresholds of 40% and 5% are used for the hysteresis thresholding parameters, which correspond to the highest and lowest threshold respectively.

Then the image is converted to Hough space and from there it is possible to extract the most relevant lines. Now a mask is created to store the pixel line's coordinates and next affect the energy map of the original image to keep this lines unaffected by the seam removal, or at least try to reduce the number of seams passing through a same line. For the algorithm, a threshold of $T_H = 100$ is used to set a parameter of how strong the lines should be in order to be considered in the list of lines returned. Then two types of parameter are input in the image that sets how many pixels have to be on a line to be considered and the maximum gap between pixels that had not be identified but can be ignored and still consider the pixels as a line, this are set to 50 and 10 respectively.

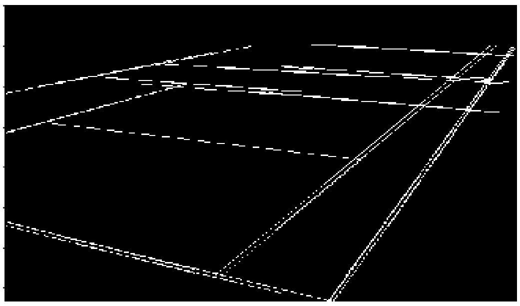


Figure 5: *Mask of lines obtained by applying the Hough transform algorithm*

After obtaining the mask is possible to use it to make modifications to the original energy map being this is the next step of the proposed algorithm. In figure 5 we can observe the mask that is obtained from the Hough transform for the same tennis court image.

3.3 Modification of the energy map to preserve lines

In seam carving modification of the original energy map of a picture is very useful to implement different kind of content aware re-sizing. As the seam carving algorithm try to find the lowest path of energy and obtaining from there the optimal seam you can, by modifying it, keep regions of interest selected by a user, produce an algorithm aware of the saliency of the picture and protecting lines, to name a few techniques.

The proposed algorithm uses the Hough transform to create a mask and then weighed this mask to later add it to the original values of the energy map. This increase the energy of the pixel that were identified in the Hough transform process and that belongs to the most important lines of our image. By increasing the energy we achieve that the seam carving algorithm will try to evade lines that are important and that will create artifacts or deformations in our scene if removed.

4 Results

In the implementation of the code we have been able to re-size input images to a desired size applying a different approach using graph theory and shortest path algorithms. We have seen that the quality of the seam has improved considerably, as shown in Figure 6 in which we have two seams, one of them (green one) has been acquired using our own implementation of dynamic programming to find the low cost path; this mean the regular seam carving algorithm. The second one (blue seam) has been acquired by our own implementation using the shortest path algorithm(Dijkstra's algorithm).
We can observe that the green one goes through the interest region, that is the cup and the blue one go through the background without removing any important part from the image.

Figure 6: *Two seam carving approaches comparison. One seam (green) is being obtained by dynamic programming and the second one (blue seam) using shortest path algorithm*

Now, as we begin removing more and more seams from the image it has been seen in different images of our data set that our algorithm even when it performs better, in relation to the calculation time, the result of re-sizing one image is similar to the one that we achieved with the dynamic programming approach. For example in Figure 7 we can observe the result of applying both methods in the same image cup, in which maybe the images are not totally different, but recognizing the difference is difficult to the human eye. So, the shortest path algorithm gives at least similar result to the common seam carving approach.

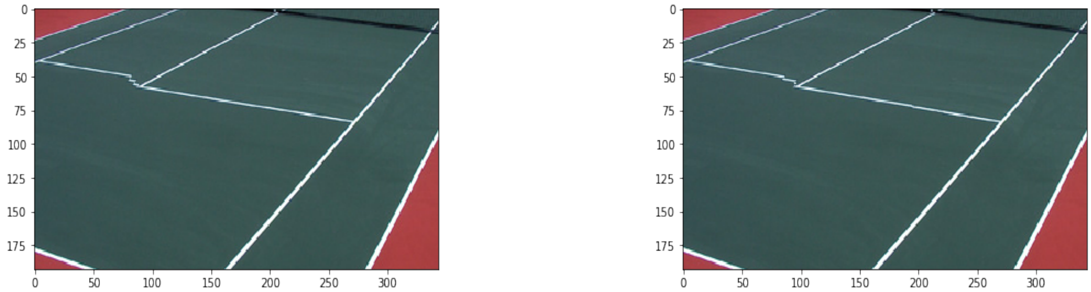
4.1 Applied Hough transform

After achieving good results with our algorithm we can use it to test the line protection algorithm using Hough transform. After, taking the image an finding the most important lines in the scene the mask is applied to the image and then the seam carving implementation is done. In the Figure 8 we can observe how our method is applied to a tennis court image.

This shows that protecting the lines of an image with Hough transform can achieve better results in the re-sizing process. This algorithm can be extended to all images re-sizing techniques using seam carving.

(a) (b)

Figure 7: Cup image with 100 seams removed on the horizontal direction applying a) the conventional seam carving approach (dynamic programming) b)Seam carving with graph implementation and shortest path algorithm



(a) (b)

Figure 8: Result of applying seam carving on an image with many straight lines. The algorithm has being applied to a) original image, b) Image with a modified energy map

5 Conclusions

Through the development of this project we could apply and have a better understanding about some of the topics taken in class. We also had the opportunity to learn about res-izing techniques making a research about the topic and implementing our own approach to a common problem.

Regarding the methods that we have used, we can say that for the seam carving approach there are a lot of considerations to be done when we want to do a proper content aware re-sizing techniques, and even when the algorithm works well for most pictures, there are some cases in which this needs to be modified to achieve better results and preserve the useful information of the image. Our methods have shown us that graph theory has a lot to give to this kind of techniques not just for reducing the computational time of the re-sizing but for improving the region conservation.

As we have seen with the Hough transform method, different kind of pictures required different kind of processing to make a real content aware re-sizing and even it needs the input of different values for the parameters to really consider what is important in the given input image. This has become the reason of why there are multiple types of algorithms that have been created for seam carving and why making an automatic algorithm that will work for every picture becomes hard to achieve.

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