Effect of cost function on seam carving

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Introduction

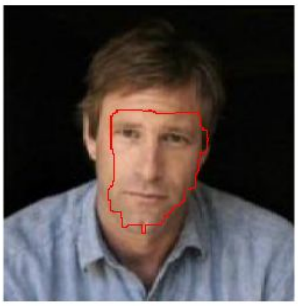
As discussed during the project demo, we were curious to understand the effect of cost function on seam carving.
At every pixel of the image we have the x-direction gradient (G_x) and the y-direction gradient (G_y). When a pixel is added to the seam, cost function (L) is incremented by a value H .

$$L = L + H,$$

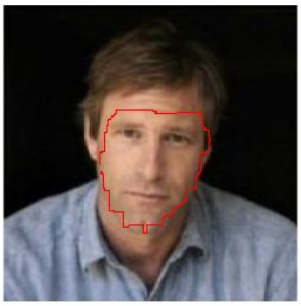
where $H = (|G_x|^p + |G_y|^p)^{1/p}$.

Observations

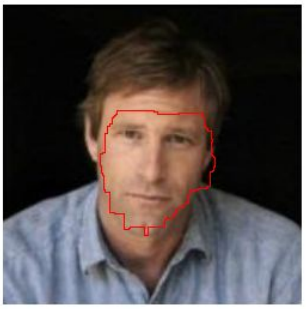
Following are the seams for $p = \{1, 2, 3, 4, 5\}$



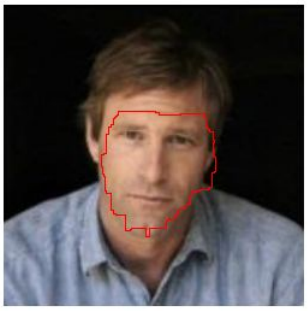
1.



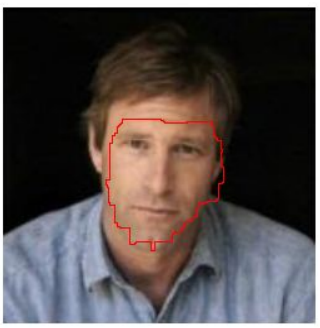
2.



3.



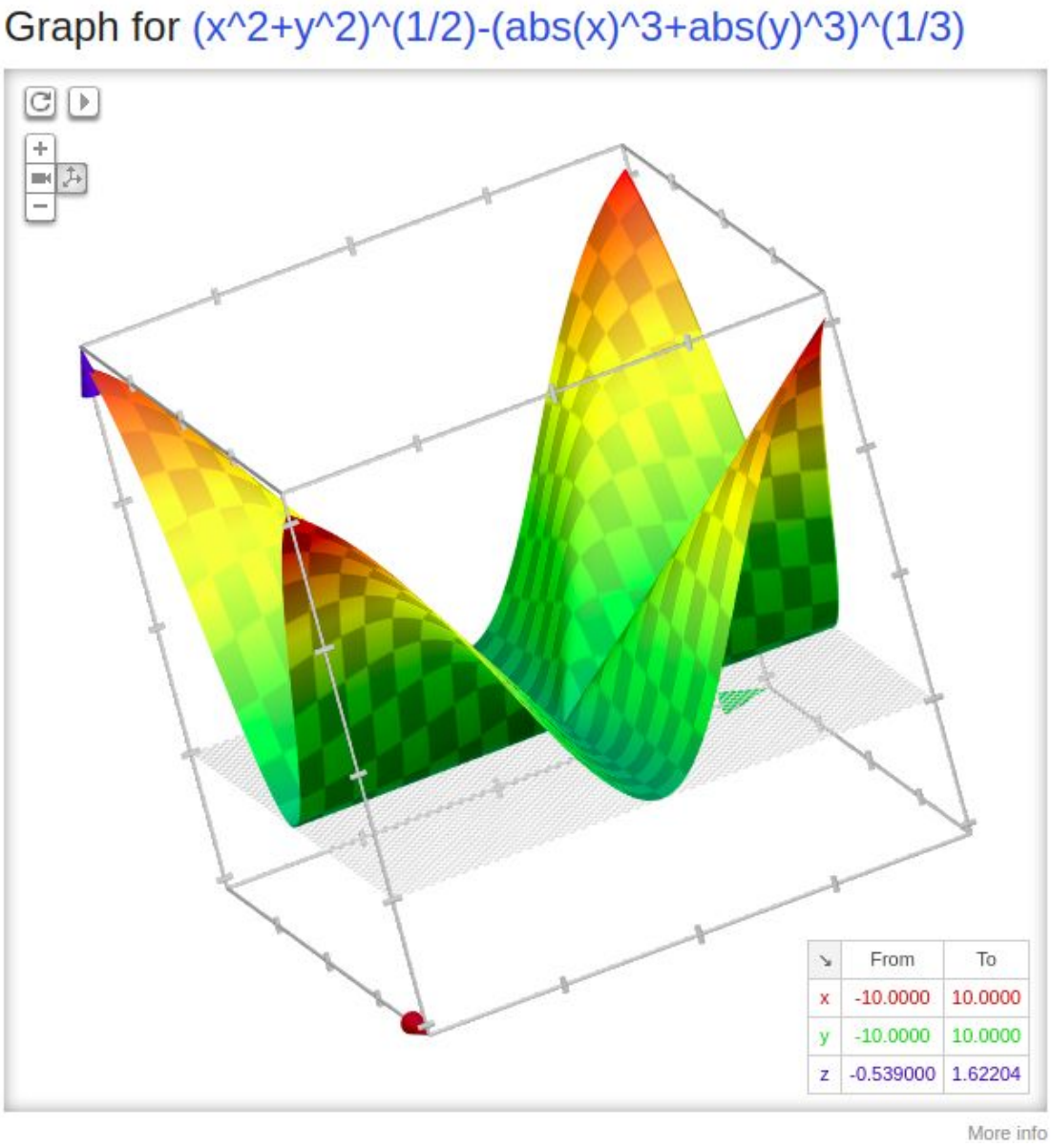
4.



5.

Explanation

In our discussion we thought that, since $x,\ x^2,\ x^3, \ldots.$ are all monotonic functions there should not be any difference in the seam but what we missed is that we should compare or $(|G_x|^3 + |G_y|^3)^{1/3}$ and $(|G_x|^2 + |G_y|^2)^{1/2}$ or $(|G_x|^2 + |G_y|^2)^{1/2}$ and $(|G_x|^1 + |G_y|^1)^{1/1}$. Below is the graph attached for difference of above quantities



There are three important facts to be noted

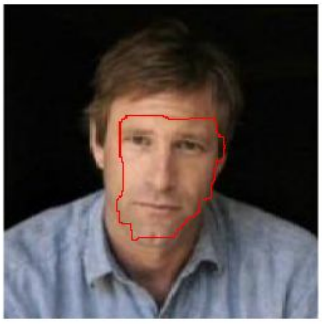
1. All the gradient values are normalized to lie with 0 and 1
2. The decrease in gradients at some points is more than that of decrease in gradient at other points. (from graph)
3. Gradient in the background of the image is zero.

At low values of p, the seam is restricted to the 'skin'-region of the face because of high 'skin'-to-'hair'-to-'background' gradient cost. But as p increases the reduction in skin-to-hair-to-gradient cost might reduce more compared to the reduction in the gradient inside the skin-region (based on the above fact#2), Due to fact#3 once the path enters the background it experience no cost as the gradient is zero.

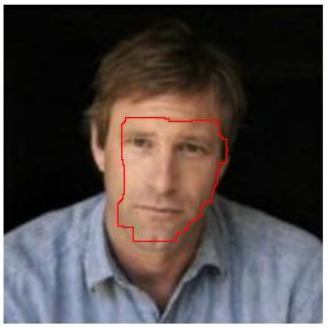
As a result we observe that the seam goes into the background of the image, traverses a low-gradient (i.e. a lost cost background) region and re-enters the face near the mouth.

Is the above explanation correct?

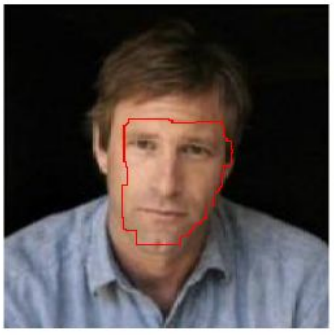
One good way to check whether the above explanation is correct or not is by adding a small constant value(0.01) to the gradient value at every pixel. Adding constant gradient is the same as saying that to penalise for the steps you take to move towards the goal. Then the seam produced should be the same for any p. Following are the seams for $p = \{1, 2, 3, 4\}$ after adding 0.01 gradient to all the points.



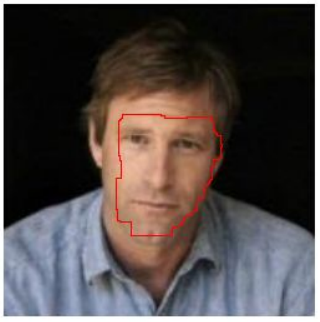
1.



2.



3.



4.

We can hardly notice any difference now, This concludes that the background having zero gradient is the main reason for the seam to move outward from face center.