Image Completion with Structure Propagation

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Jian Sun, Lu Yuan, Jiaya Jia, and Heung-Yeung Shum. Image completion with structure propagation. In *SIGGRAPH '05: ACM SIGGRAPH 2005 Papers*, pages 861–868, New York, NY, USA, 2005. ACM

Image completion, also known as image inpainting, refers to the synthesizing of a missing part of an image using the remaining information. While it is related to texture synthesis, the main focus of image completion is the extension of salient image features into the unknown region, which makes the result visually plausible. To perform such a task perfectly, human expertise is typically needed; however, many techniques have been proposed that are automated to various degrees.

Structure propagation is a sophisticated inpainting technique that first performs synthesis in the vicinity of a curve network that is specified interactively. This part of the procedure provides the ability to restore sharp edges, such as the profile of a mountain seen against a sky background. The curve network also partitions the image into regions overlapping the unknown area. This allows the second step of structure propagation to perform texture synthesis separately in each of the regions to complete the image.

A primitive operation used in both of the synthesis operations is to select a suitable image patch, or fixed-size square block of pixels, and to paste it at the location being processed. The patches are taken from the valid regions of the input image and can be rotated first to provide a better match. The pasting is not a direct copy, but uses an interpolation technique called Poisson editing to blend in the patches at the destination location. For the first step of image completion, patch selection is formulated as a global optimization problem, which is solved using dynamic programming in the case of a single curve, and belief propagation in the general case.

The results of using structure propagation are outstanding. In one instance, the front of a train car has been synthesized, which has required fitting window detail from another area of the image. Such a problem is more underconstrained compared to the situation when it is sufficient to have the curves pass through the unknown region, providing clear boundary conditions. That this type of problem is within the scope of structure propagation indicates that its optimization algorithm is robust.

One weakness of the technique is that it uses image patches of the same constant size everywhere. Since the patch size must be large enough to capture the appropriate feature size along all structure-representing curves, the common patch size ends up being the maximum of the sizes necessary for each individual structure. Although the artifacts resulting from pasting large patches are barely noticeable due to the use of Poisson editing, large patches can cause other problems. For example, if two patches lying on neighbouring non-intersecting curves are too large, they can either overlap, which may not be handled by the optimization algorithm properly, or leave too small a gap for the texture synthesis stage, so that Poisson editing will not be able to improve the blending significantly.

As for the degree of automation that structure propagation provides, there is one case when it is less than optimal, which is discussed in the paper. Since the curve network does not encode visibility order (i.e. which of the structures corresponding to a pair of intersecting curves is on top), some problem instances require the image to be manually separated into layers that have to be processed individually.