Enhancing Super-Resolution with Local Similarities

Literature Review #3 - COMP.5460

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SUPER-RESOLUTION

Super-resolution is the compilation of multiple low-resolution images to form one, high-resolution image [1]. It has many uses in the world of graphics, for instance, in three-dimensional scanners, object acquisition devices, and the computation of pixels in image translations. As with any algorithm, we will always strive to improve its implementation and consequently its run time. For super-resolution algorithms this proves to be a challenge since it inherently has a large overhead due to the processing of high-resolution 3D images. This begs the question, how do we improve said algorithm?

IMPROVING SUPER-RESOLUTION

To improve an algorithm we need to understand how it works first, then we can see where there is room for improvement. In a scene, we can usually expect that there is a small movement between itself and the camera [1]. In this case, the first step of a super-resolution algorithm would be to align the images and calculate the motion of pixels from one image to another. This motion could be as simple as a translation, shear, or scale, but can get as complex as optical flow fields. Once the images are aligned, we move onto the next step, which is to fuse the newly aligned images into one, high-resolution image.

The second step usually takes advantage of reconstruction constraints that should have been generated in the first step. These constraints can be fed into a Bayesian framework to which the results will be estimated in batch more or done recursively using a Kalman filter. Unfortunately, these reconstruction constraints have a mixed result when applied to real-world applications. Though the resulting super-resolution images look better when compared to the inputs, they aren't constructed as well as one would hope, so the images on their own still look distorted to some extent.

Now we can start to see where the algorithm can improve. Clearly, the reconstruction constraints could use a little tweaking since the results aren't as clear as desired. Baker et al propose a new method that adds a new type of constraint that will enhance low-resolution images to high-resolution images where appropriate [1].

”HALLUCINATION” ALGORITHM

This new approach, dubbed a Hallucination algorithm, utilizes a set of recognition decisions on the solution of the recognition constraints. To summarize the extensive mathematics behind it, it attempts to extract local features from the low-resolution images so that it can use that information when it creates the high-resolution image. The resulting images turned out to be better qualitatively and in RMS pixel error when compared to their older counterparts.

This is one of the first approaches to super-resolution that use the power of local features of an image to make it faster and better to interpolate them to high-res images. 16 years later, local features, more specifically local similarities, are used to optimize the super-resolution of point set surfaces.

POINT SET SURFACES

As mentioned earlier, super-resolution has useful applications in several graphics topics. I’ll move on from the interpolation of existing images to the mapping of real-world images to the virtual world.

An object in the real-world can be mapped to an image on a computer using a 3D scanner. The scanner will in turn create a point set, to which a computer can convert that to a surface (aptly named a point set surface). A point set’s accuracy relies on the accuracy of the scanner itself. Typically, these scanners produce a small amount of noise on the object that distorts it slightly. To fix this, the point set surfaces often are put through a procedure that will get rid of the noise and create a higher-resolution representation of the object. Not surprisingly, a super-resolution algorithm is ideal for a situation like this.

Unlike the use case in the beginning, a super-resolution algorithm for 3D scanners can’t rely on the fusion of several low-resolution images to form a high-resolution one. Taking several scans of the same object would take up much more space, and it would require a lot of computing power to compare all those point sets. Fortunately, a new method has been found by Hamdi-Cherif et al that will produce a high-resolution image from one scan alone, and quickly at that [2]. This method takes advantage of local similarities to efficiently scale up a point set.

UTILIZING LOCAL SIMILARITIES

This new method is a new approach to surface super-resolution. It detects repetitive patterns and similarities and uses them to improve the resolution by aggregating scattered measures [2]. Compared to previous methods, it has a couple of advantages.

One is that it does not rely on surface registration from multiple scans to make it higher-resolution. As stated earlier, the processing of multiple scans would take a lot of computing power not only to load the values into a point set, but to compare those point sets as well. By skipping the surface registration for each of the scans, it inherently speeds up the run time.

Another advantage is it is able to produce a super-resolution scan from one image alone. Even though this new method wouldn't need to register multiple surfaces from multiple scans, it wouldn't need the other scans to begin with. This saves on the space required to process a point set. With these two advantages, the run time increases and the space required decreases, proving a substantial improvement to older super-resolution algorithms.

By comparing a portion of a surface with its surroundings we can find useful information that will speed up the rest of the interpolation. For instance, if the algorithm recognizes a pattern along a surface, like a zipper for instance, it can apply that similarity to the rest of the surface even in the scanner creates unwanted noise in certain spots. Not only can it recognize patterns, but it can help define the area around a certain point on the surface. For example, a scan of a perfectly concave bowl may show some surface imperfections due to an imperfect scanner. The new algorithm for super-resolution can detect that its surroundings are all perfectly even and can reduce the noise generated.

CONCLUSION

We've seen how super-resolution algorithms have improved over time, and how they can be tweaked slightly to work over a broad variety of graphical implementations. The up-scaling of images, point set surface improvement, and other techniques can directly take advantage of the power given by local similarities.

Bibliography

[1] S. Baker and T. Kanade, “Limits on super-resolution and how to break them,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 24, pp. 1167–1183, Sep 2002.

[2] A. HamdiCherif, J. Digne, and R. Chaine, “Superresolution of point set surfaces using local similarities,” *Computer Graphics Forum*, vol. 37, no. 1, pp. 60–70.