Fight ill-posedness with ill-posedness: Single-shot variational depth super-resolution from shading

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Abstract

The paper put forward a principled variational approach for up-sampling a single depth map to the resolution of the companion color image provided by an RGB-D sensor. They combined heterogeneous depth and color data in order to jointly solve the ill-posed depth super-resolution and shape-from-shading problem. The low-frequency geometric information necessary to disambiguate shape-from-shading is extracted from the low-resolution depth measurements and, symmetrically, the high-resolution photometric clues in the RGB image provided the-frequency information required to disambiguate depth super-resolution.

1. Introduction

RGB-D senesors have become very popular for 3D-reconstruction, in view of their low cost and ease of use. They delivery a colored point cloud in a single shot, but the resulting shape often misses thin geometric structures. This is due to noise, quantisation and, more importantly, the coarse resolution of the depth map. However, super-resolution of a solitary depth map without additional constraints is an ill-posed problem such as figure. 1.

The resolution of the depth map thus remains a limiting factor in single-shot RGB-D sensing. This work aims at breaking this barrier by jointly refining and upsamping the depth map using shape-from-shading. In other words, **they fight the ill-posedness of single depth image super-resolution using shape-from-shafing, and vice-versa.**

2. Motivation and Related Work

Due to hardware constraints, the depth observation z_0 are limited by the resolution of the sensor(*i.e.*, the number of pixels in Ω_{HR}). The single depth image super-resolution problem consists in estimating high-resolution depth map: $z : \Omega_{HR} \to R$ over a larger domain $\Omega_{HR} \supset \Omega_{LR}$, which coincides with the low-resolution observations z_0 over Ω once it is downsampled. Following [1], this can be formally

Figure 1. They carry out single-shot depth super-resolution for commodity RGB-D sensors, using shape-from-shading. By combining low-resolution depth (left) and highresolution color clues (middle), detail-preserving superresolution is achieved (right). All figures best viewed in the electronic version [2].

written as

$$z_0 = K_z + \eta_z \tag{1}$$

In Eq. 1, $K : R^{\Omega_{HR}} \to R^{\Omega_{LR}}$ is a linear operator combining warping, blurring and downsampling [4]. It can be calibrated beforhand, hence assumed to be knuwn, see for instance [3]. As for η_z, it stands for the realisation of some stochastic process representing measurement errors, quantisation, *etc*.

3. Conclusions

Today I start reading the paper of *Fight ill-posedness with ill-posedness: Single-shot variational depth super-resolution from shading*. The paper will be seperated by several part to be understand. This is the first part.

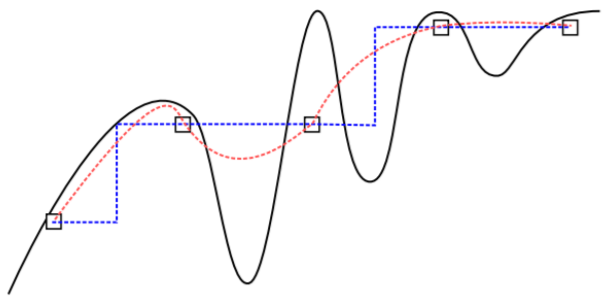

Figure 2. There exist infinitely many ways (dashed lines) to interpolate between low-resolution depth samples (rectangles). Our disambiguation strategy builds upon shape-fromshading applied to the companion high-resolution color image (*cf.* Figure 3), in order to resurrect the fine-scale geometric details of the genuine surface (solid line). [2].

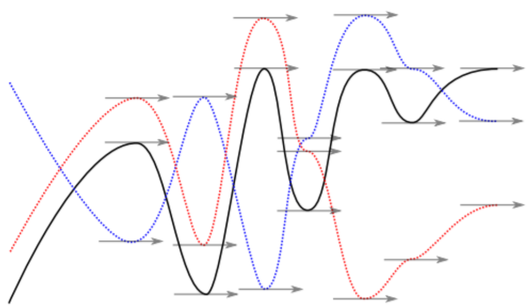

Figure 3. Shape-from-shading suffers from the concave / convex ambiguity: the genuine surface (solid line) and both the surfaces depicted by dashed lines produce the same image, if lit and viewed from above. We put forward lowresolution depth clues (*cf.* Figure 2) for disambiguation. [2].

References

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