

LETTER

Automatic and Accurate 3D Measurement Based on RGBD Saliency Detection

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SUMMARY The 3D measurement is widely required in modern industries. In this letter, a method based on the RGBD saliency detection with depth range adjusting (RGBD-DRA) is proposed for 3D measurement. By using superpixels and prior maps, RGBD saliency detection is utilized to detect and measure the target object automatically. Meanwhile, the proposed depth range adjusting is processing while measuring to prompt the measuring accuracy further. The experimental results demonstrate the proposed method automatic and accurate, with 3 mm and 3.77% maximum deviation value and rate, respectively.

key words: 3D measurement, RGBD saliency detection, saliency map, depth range adjusting, superpixel

1. Introduction

With 3D sensor advance, the automatic 3D measurement is developed as an efficient solution instead of traditional manual measuring, in the applications of logistic transportation, intelligent warehousing, trade settlement, *etc.*. The method of salient object detection can separate the object from the background achieves superior performances [1]. The depth information, which is acquired from the 3D sensor to measure the size of the object in the spindle direction [2], but also can be used to assist saliency object detection. Moreover, as 3D sensor technologies, despite the time of flight (ToF) provides excellent ability and flexibility, the sectoring emitted light leads to the inevitable measuring deviation [3].

The work proposes an automatic and accurate 3D measurement method based on RGBD saliency detection with depth range adjusting (RGBD-DRA). The superpixels and prior maps are utilized to detect and measure target object automatically. Furthermore, the depth range adjusting is adopted to improve the measuring accuracy.

2. Proposed Method

In our proposed method, firstly the RGB image is converted to the CIE-LAB color space, which is over-segmented into superpixels using SLIC algorithm [4]. For each superpixel r_i , its saliency value is measured with respect to all other superpixels. There are three kinds of prior maps utilized to perform saliency detection, such as the background, depth,

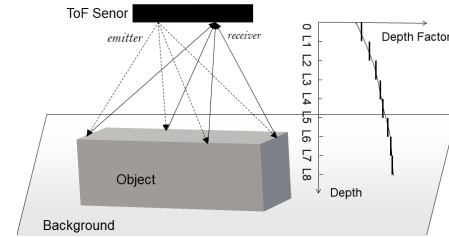


Fig. 1 The illusion of ToF and depth range adjusting.

and surface orientation prior maps. The boundary connectivity, which is adopted to generate the background prior map [5], is defined as

$$S_{bp}(r_i) = 1 - \exp\left(-\frac{L(r_i)^2}{2\chi_b^2 A(r_i)}\right) \quad (1)$$

where for the region r_i , $L(r_i)$, $A(r_i)$, and χ_b indicate the length along the boundary, the area, and the boundary connectivity weighting factor, respectively. The depth prior map, which reflects the influence of positions in different depth field, is defined as

$$S_{dp}(r_i) = \sqrt{1 - d(r_i)} \quad (2)$$

where $d(r_i)$ is the mean depth value of the region r_i . All depth value of regions are normalized and rescaled into the range [0, 1]. Assuming that the direction perpendicular to the principal axis receives the most attention [5], the surface orientation prior is also introduced as

$$S_{op}(r_i) = \langle \mathbf{z}, \mathbf{n}(r_i) \rangle \quad (3)$$

where \mathbf{z} and $\mathbf{n}(r_i)$ are the principal axis and the region r_i surface normal, respectively. The $\langle \rangle$ denotes the inner product. The salient values of each superpixel are assembled together to form the salient maps S_{bp} , S_{dp} , and S_{op} . They are multiplied element by element to generate the saliency map for measuring as $S_m = S_{bp} \cdot S_{dp} \cdot S_{op}$. Finally, the salient object can be detected on the saliency map through *Otsu* threshold algorithm. And the $L_{original}$ and width $W_{original}$ of the detected object are achieved based on pixel calibration.

During saliency detection depth range adjusting is adopted to improve the measuring accuracy further as the whole scene is quantized into several levels as shown in Fig. 1. Assuming that the Gaussian kernel function is used to measure the effect of the distance, the influence of the depth information yields $\mathcal{N}(0, \sigma^2)$, that the depth factors D

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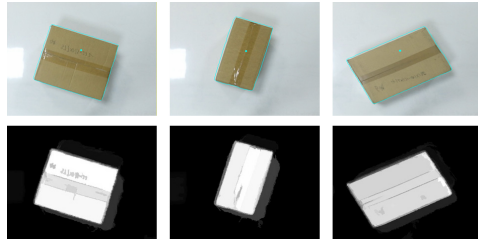


Fig. 2 The automatic detection and measurement using saliency maps.

can be achieved as

$$D = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{x^2}{2\sigma^2}\right) \quad (4)$$

where x and σ^2 denote the space from object to sensor and the covariance, respectively. The \mathcal{F} is defined as factors set, which has i elements, $i \in \{1, 2, \dots, \text{levelnumber}\}$.

$$\mathcal{F}_i = \frac{1}{N} \int_{\text{level}_i \text{ lower-boundary}}^{\text{level}_i \text{ upper-boundary}} D dx \quad (5)$$

where N is the normalization factor which indicates the range of each level. H_{original} can be achieved by the ToF sensor directly. The adjust factors are applied to adjust the height, length, and width by $\{H_{\text{adjusted}} = \mathcal{F}_i H_{\text{original}}, L_{\text{adjusted}} = \mathcal{F}_i L_{\text{original}}, \text{ and } W_{\text{adjusted}} = \mathcal{F}_i W_{\text{original}}\}$, respectively. Where \mathcal{F}_i denotes the depth range adjusting factor in level i , which can be determined by H_{original} preliminary.

3. Experimental Results

In the experiments of proposed saliency detection method as shown in Fig. 2, the first row displays three samples to measure. The second row displays the saliency maps which indicate the objects clearly and contains the depth information. After data conversion and processing with depth range adjusting, the target objects are detected and measured without any manual intervention. Table 1 shows the 3D measurement results for 8 regular cartons samples. Compared to ground truth, there are inevitable deviations exist in 3D measuring based on RGBD saliency detection without or with depth range adjusting (RGBD or RGBD-DRA). However, as shown in Fig. 3 the RGBD-DRA presents more accurate measurement results, whose H , L , and W are closer to the ground truth, with 3 mm and 3.77% maximum deviation value and rate, respectively.

4. Conclusion

In this letter, we proposed a method for 3D measurement based on RGBD saliency detection with depth range adjusting. The experimental results show that the proposed method can detect the target object and acquire its 3D infor-

Table 1 The measurement of 8 samples in W, L, H [unit: mm].

	Ground Truth	RGBD	RGBD-DRA
#1	109, 82, 83	104, 80, 82	107, 82, 84
#2	133, 128, 90	130, 122, 90	133, 129, 90
#3	247, 168, 110	242, 163, 108	246, 166, 110
#4	315, 163, 53	312, 160, 49	313, 164, 51
#5	365, 207, 200	360, 200, 198	363, 208, 200
#6	377, 313, 222	372, 308, 215	376, 311, 220
#7	412, 275, 180	408, 270, 178	410, 274, 179
#8	468, 458, 463	464, 450, 462	467, 455, 463

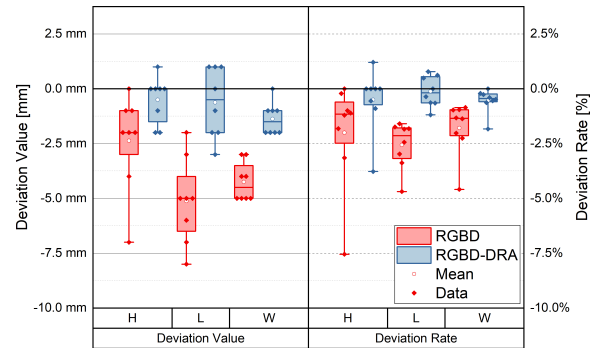


Fig. 3 The measurement deviation of RGBD and RGBD-DRA.

mation automatically, with advanced measurement accuracy resulting from depth range adjusting.

Acknowledgments

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References

- [1] A. Borji, M.M. Cheng, H. Jiang, and J. Li, "Salient object detection: A benchmark," *IEEE transactions on image processing*, vol.24, no.12, pp.5706–5722, 2015.
- [2] K. Desingh, M. Krishna K, D. Rajan, and C. Jawahar, "Depth really matters: Improving visual salient region detection with depth," *BMVC*, pp.98.1–98.11, 2013.
- [3] C. Lang, T.V. Nguyen, H. Katti, K. Yadati, M. Kankanhalli, and S. Yan, "Depth matters: Influence of depth cues on visual saliency," *Computer vision–ECCV 2012*, vol.7573, pp.101–115, Springer, 2012.
- [4] R. Achanta, A. Shaji, K. Smith, A. Lucchi, P. Fua, S. Süsstrunk, "Slic superpixels compared to state-of-the-art superpixel methods," *IEEE transactions on pattern analysis and machine intelligence*, vol.34, no.11, pp.2274–2282, 2012.
- [5] J. Ren, X. Gong, L. Yu, W. Zhou, and M. Ying Yang, "Exploiting global priors for rgb-d saliency detection," *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, pp.25–32, 2015.