Processing for laser radar range images

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Imaging laser radar can give intensity and range images, which provide integrated 3-dimensional (3D) information about objects. However, dropouts and range anomalies exacerbate range images, which makes their background cluttered and target blurred. For background suppression, a new algorithm that combines intensity image and its mean is presented. By using this algorithm to process actual laser radar range images, most background noises are suppressed. According to range anomalies characteristics, multi-template selection order mean filtering algorithm is presented and used for actual ladar range images where the distance between two targets is 77 m. This algorithm obtains the clear range image in which the interval of two objects is 75 m. The result shows that the processing algorithm is correct and effective.

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Imaging laser radar is capable of producing intensity and range images. Plenty of work has been done on intensity image processing[1−3], but literatures about laser radar range images processing are very few. Only reading out target information in intensity and range images accurately, laser radars can perfectly provide the 3-dimensional (3D) information (intensity and range) and make it ready for target recognition and position, which is the advantage that active imaging radars have as compared with other imaging approaches. So it is badly necessary and crucial to study active imaging radars range imagery processing.

Missing values which deteriorate range images quality badly exist in range imagery. The missing value pixel is either a dropout pixel or an outlier pixel[4].

The following circumstances will produce dropout pixels: first, there is no return for the corresponding transmitted pulse such as no reflecting surface in the pulse's path (for example sky); second, the time when the returning wave goes beyond the receive window. When the measured range departs from the true range, the corresponding pixels are outliers. Because outlier behaves with range anomalies, it is also termed as range anomalies[5−7].

Dropouts occur where there are no objects, and range anomaly often exists where there are objects. Dropouts make the background of the range image disorder and the range anomalies lead to the blur of object information. So the noise processing of range image contains two steps: the eliminate of dropouts and the suppression of range anomalies.

It is extremely hard to eliminate dropouts. Dropouts of range image were eliminated by combining the information of intensity image and the range image[4]. Verly processed it by using the mean information of the raw intensity image, which made unsatisfactory result. But such method that combines the intensity image information gives us useful illumination.

Green suppressed the range anomalies by using expectation-maximization (EM) algorithm which based on maximum-likelihood[5]. He did it by combining the EM algorithm and multiresolution. Better result was obtained. But because of the typical characteristic of the EM algorithm, which needs to iterative again and again till to get stable convergent result, such algorithm needs lots of time and does not suit for real-time process.

Figure 1 presents the photo of two objects whose fore and aft interval is 77 m. Ladar intensity image samples by 256 gray-level and range image does 8 as well. Figure 2 shows the raw intensity and range images of ladar. It looks like that there is only a single object, which thought to be the mistake of only reading from the intensity image

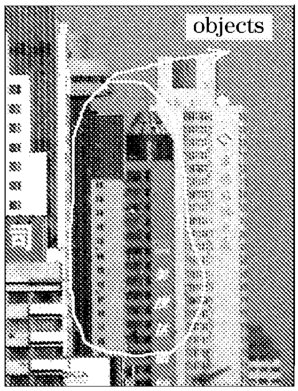

Fig. 1. Photo of the objects.

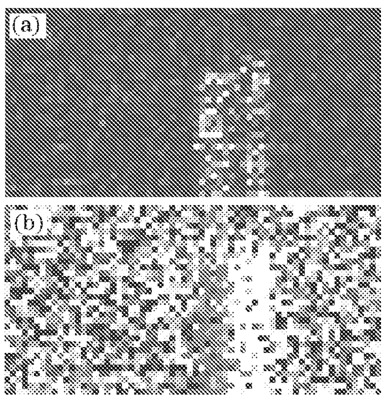

Fig. 2. Raw radar images. (a) Raw intensity image; (b) raw range image.

in Fig. 2(a), we can distinguish the two objects clearly by combining the intensity image with the range images, thus responds the advantage of active imaging laser radar adequately.

Figure 3(a) shows the result of the dropout suppression by Verly using the mean of the raw intensity image. Comparing with the raw range image, the range image is improved markedly, although the effect is not very good. Not only lots of dropouts are not eliminate but also some information belonging to the object is lost. The better the effect by increasing the threshold, the more the losses in the information of the object.

In order in the suppression of the background more effectively, we present an improved algorithm based on combination of the filtered and mean information of the intensity image. Figure 3(b) gives its results, where background is suppressed effectively while object's information hardly loses. This algorithm for suppressing background can also be used to suppress intensity images' background and the preprocess before segmentation of other images affected by noise.

After the background suppression of the range images, the suppression of the range anomaly in range images is studied.

When laser beams illuminate object's surface, laser speckle occurs inevitably because of the roughness of the surface. At the same time, it will be affected by local oscillator shot noise in optical heterodyne system. The integration of the above two noises brings the range anomalies[5], as shown in Fig. 4.

The conjunction of a deep speckle fade with a strong noise peak can lead to a range measurement (R) far removed from the true range (R^*), then range anomaly forms. Let r denote the measured range value whose true range value is r^*. Reference [5] presented the probability density function (PDF) for $r = R$, given $r^* = R^*$, which is

$$P_{r|r^*}(R|R^*) = [1 - P_r(A)]\frac{\exp[-\frac{(R-R^*)^2}{2\delta R^2}]}{(2\pi\delta R^2)^{1/2}} + \frac{P_r(A)}{\Delta R},$$

$$R_{\min} \le R, R^* \le R_{\max}, \qquad (1)$$

where $P_r(A)$ denotes the anomaly probability, i.e. the probability that range anomaly appears, δR denotes local range accuracy, and $\Delta R = R_{\max} - R_{\min}$ denotes range-uncertainty interval.

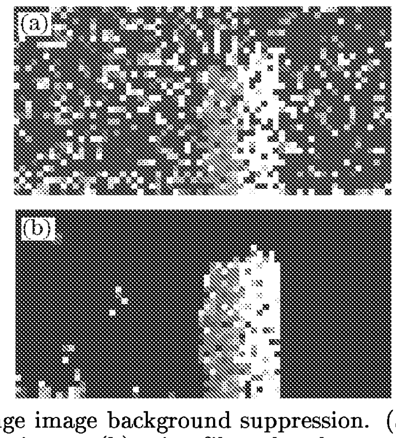

Fig. 3. Range image background suppression. (a) Using the raw intensity image; (b) using filtered and mean information.

In Eq. (1), the first term on the right represents the local range behavior that the measurement is not anomalous, and the probability that the behavior occurs equals to the Gaussian probability whose mean equal to the true range R^* and standard deviation equals to the local range accuracy δR. The second term represents anomalous range measurement encountered the conjunct effects of the speckle and shot noise, while range measurement puts up uniform probability inside range measurement interval arising from stochastic noise.

In order to meet the need of real-time processing, we put forward a fast and effective algorithm, that is MT-SOMF (multi-template selection order mean filtering) algorithm based on the model of range noise behavior.

Figure 5 shows the multi-template structure.

Let M denote the template, the algorithm is described as

$$\begin{cases} y_k = k\text{th order statistic of } \{x_{i+r,j+s}; (r,s) \in M\} \\ z_{i,j} = \frac{1}{k_2-k_1+1}\sum_{k=k_1}^{k_2} y_k \end{cases}. \qquad (2)$$

In this formula $z_{i,j}$ is the filtered grayscale value, k_1 and k_2 are the upper limit and the lower limit, respectively.

Figure 6 shows the result by using such filtering algorithm.

We can find from Fig. 6 that the range anomalies are suppressed effectively and even range values of each object are obtained.

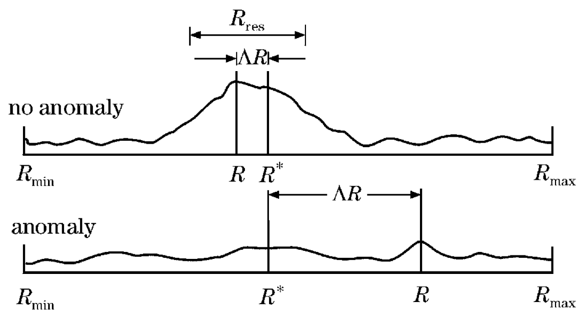

Fig. 4. Normal and anomalous behavior in peak detection range measurement.

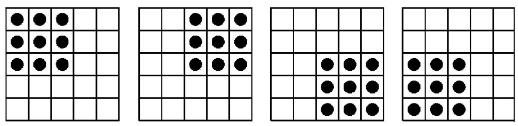

Fig. 5. The multi-template structures.

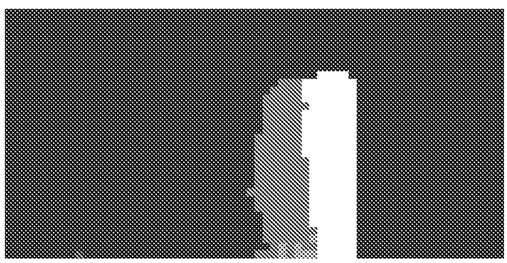

Fig. 6. Processed range image.

In conclusion, we present a new algorithm for suppressing the background and eliminating the range anomaly of range image in imaging laser radars. It is used to process range image and clear range image is achieved. The range information from the processed range image shows that the distance between the two object is 75 m, reflecting the actual objects' interval (77 m) exactly. The practicability of the algorithm is well proved.

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