Study of image reconstructions of Indonesian traffic sign using Criminisi and Hung method

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Abstract. Image reconstruction of traffic signs serves in order to improve the image quality of traffic signs that are covered leaves, tree branches or pole so that it can facilitate the process of recognize or detecting traffic signs. Inpainting is one of the image restoration methods to reconstruct images that have been damaged or the removal of unwanted objects where the area to be restored is based on information around the area. Criminisi introduces an inpainting method with an exemplar-based approach that combines the structure-oriented and texture-oriented scheme. While Hung popularized the Criminisi method and combined it with contour construction (Bezier curve). The researcher tried to compare the two methods by using a number of images of traffic signs, one of them by using images with a size of 400 x 407 pixels, issuing the results of Peak Signal to Noise Ratio (PSNR), the Criminisi method gets results from PSNR 36,479 decibel (dB), while the Hung method gets results from PSNR 36,827 dB. This means the result of Hung method is more similar to original image than Criminisi method.

1. Introduction

Traffic signs are one of the road equipment which can be in the form of symbols, letters, numbers, sentences or combinations of them which serve as warnings, prohibitions, orders or instructions for road users [1]. Traffic signs are one form of information needed by drivers, detection and recognition of signs or Autonomous Driving System, so that it is needed with the quality of the image of a good traffic sign [2-5]. Many times, drivers encounter road equipment experiencing natural problems caused by obstructed twigs of trees, leaves of trees, and other traffic signs that are difficult for motorists to recognize.

Inpainting is one method of image restoration to reconstruct images that have been damaged or removed from unwanted objects where the area to be restored is based on information around the area such that the restoration is carried out completely in that area. Bertalmio introduced a pixel synthesized approach with structure oriented schemes to fill in missing areas based on isophote information (linear structure propagation). When applied to a large enough target area, it will produce a blurred image [6].

Criminisi introduces an inpainting method with an exemplar-based approach that combines a structure oriented and texture oriented scheme [7]. This method requires a process to do texture synthesis while improving linear structure. Inpainting is done by utilizing texture information (represented in
confidence terms) and isophote information or structure (data term). Both of these information is used to determine the priority of the order in which the target area is filled.

Whereas Hung popularized the Criminisi method by combining contour construction [8]. Linear structure information is not taken from the isophote image value but from the results of contour construction in the target area. Contour construction is carried out using the bezier curve method.

2. Indonesian traffic sign dataset
To evaluate the results of reconstructing the image of Indonesian traffic signs, has been created a dataset on the image of Indonesian traffic signs, shown in figure 1.

![Indonesian Traffic Signs](image)

**Figure 1.** Indonesian traffic sign dataset.

The new dataset has been simulated that are, 221 datasets according to the image of Indonesian traffic signs of different sizes. The dataset has approximately missing conditions from the Mean Squared Error (MSE) value 423,235 to 8943,175, for simulating missing images or unwanted objects using green RGB [0 255 0]. The dataset and test results can be downloaded in = bit.ly/30K0sqM

3. The methods
The reconstruction of the image of Indonesian traffic signs has been applied by using an adaptation of the Criminisi method or Hung method [7,8], in order to find out good results, we try to compare the two methods and get results in this works.

3.1. Adaptation of the Criminisi method
The adaptation to the Criminisi method has been applied.

3.1.1. Preprocessing. In this subsystem, defined image areas to be deleted. Furthermore, the area to be removed is used as the target area while other areas around it are used as source areas. From the target area boundary, a Region of Interest (ROI) limit is determined in the form of a square with the target area as the center. Defined ROI which is the source image that is within the ROI limit. Further processing is done only on ROI. Then the ROI is converted into grayscale. The modified gray image contrasted with histogram equalization in order to make it sharper (optional).
3.1.2. **Edge detection.** In this subsystem, in the edge detection has been done in order to obtain the contours of the image in the source area. The algorithm used for edge detection is Canny Edge algorithm [9]. The image is processed first with Gaussian filtering (standard deviation $s = 1.4$) to reduce noise. Next, the image gradients are calculated, so the edges are obtained but they are still thick in size. The edge is thinned with non-maximum suppression which sees the local maximum on the edge. The edges of the thinning result are categorized using two thresholds (double thresholding), namely the upper threshold and bottom threshold. The edge whose value is above the upper threshold (strong category) and between the top-down threshold (weak category) is maintained. Whereas the edge under the lower threshold (waste category) is discarded. Next is edge tracking. The weak category edge will be maintained if there is a strong Edge around it. If it doesn’t exist, the edge of the weak category is discarded.

3.1.3. **Exemplar-based inpainting.** The exemplar-based is the process of filling the target area with pieces replicated from the source area. The method is used in this subsystem adapts the Criminisi method [9].

a. **Patch priority calculation**

Calculate the priority of each patch (1) and take the patch with the highest priority, determined the attribute:

$$p(p) = C(p) \cdot D(p).$$

Calculate the confidence term with the Equation (2):

$$\forall p \in \delta \Omega, C(p) = \frac{\sum_{q \in \psi_p \cap (I - \Omega) \cdot C(q)} |\psi_p|}{(2)}$$

Calculate the data term with the Equation (3):

$$D(p) = \frac{\| \nabla I_p \cdot n_p \|_a}{(3)}$$

b. **Search and insert exemplar**

The appropriate pieces to fill the target area determined with Equations (4):

$$\psi_q = \min_{\psi_r \in \Phi} (d(\psi_p, \psi_q) + d(r(\psi_p), r(\psi_q)))$$

where,

- $d$: the size of the similarity selected.
- $\Phi_q \subset \Phi$: all regions that are in the source area of the image with the center $q$ and radius $r$.
- $r(\psi_p)$: snippets taken from binary imagery resulting from contour construction with the same position as $\psi_p$.

The size of the similarity $d$ is calculated in the CIE L * a * b * color space, after all the priority on the charging front has been calculated, patch with the highest priority is found. then the data extracted from the source area $\Phi$ are a substitute.

c. **Update confidence term**

The confidence term value is updated for new pieces that arise due to the insertion of copies. Update confidence term is done with Equation (5):

$$C(p) = C(p^*) \quad \forall p \in \psi^* \cap \Omega.$$

(5)
3.2. Adaptation of the Hung method
Hung introduced an adaptive approach criminisi is approach added by using contour construction [8]. Linear structure information is not taken from the isophote image value but from the results of contour construction in the target area. Contour construction is done by using the bezier curve method.

3.2.1. Contour construction
The contour construction in the target area based on the Edge of the image of Indonesian traffic signs. Construction is done by first determining the point pairs as the end control points (beginning and end) of the Bezier curve [10], then the point is connected to the Bezier curve. The steps of Edge construction are applied by an adaptation approach [8].

4. Results and discussion
The implementation of image reconstruction for Indonesian images traffic signs use the criminisi or hung method adaptation. To find out the results of both and also the visualization, the authors tried to compare the two methods in Matlab 2016.

4.1. Testing
After getting the results of reconstructing images of Indonesian traffic signs, it can be seen visually or from Peak Signal to Noise Ratio (PSNR), to compare a level of similarity between the original image with a result image reconstruction. the value of PSNR [11], is achieved by comparing the original image pixel from the image reconstruction, the higher the PSNR value, the better the image produced.

4.2. The results of testing the traffic signs simulation
The reconstruction result simulation images of the Indonesian traffic signs are shown in figure 2:

![Figure 2](image-url)

Figure 2. The result of visual comparison of both methods.

Figure 2 shows a visual comparison of the two methods, (A01), (B51) and (C01) is a simulation of Indonesian traffic signs, (A01a), (B51a) and (C01a) is a mask to the image of a traffic sign that is simulated in green, (A01b), (B51b) and (C01b) is the result of reconstructing image a traffic sign from the adaptation Criminisi method, whereas (A01c), (B51c) and (C01c) are the results reconstruction image traffic signs from adaptation Hung method. With a small mask size, visually It means that the Hung Method was more applicable than Criminisi Method.
Table 1. PSNR values comparison for the Indonesian traffic signs simulation.

| Image | Size   | MSE Mask | PSNR Criminisi method adaptation | PSNR Hung method adaptation |
|-------|--------|----------|----------------------------------|-----------------------------|
| A01   | 240 x 240 | 726,484 | 24,149                           | 28,971                      |
| B51   | 123 x 116 | 2559,727| 29,698                           | 29,803                      |
| C01   | 149 x 182 | 2156,239| 29,765                           | 45,485                      |

From several images for the Indonesian traffic signs simulation table 1, shows the average of PSNR value of the adaptation criminisi method is smaller than the adaptation hung method, it means that the Hung method was more applicable than Criminisi method.

4.3. The results of testing the Indonesian image traffic signs

Figure 3, Figure 4 and Figure 5 show that the cropping images has been applied in order to recognize the Indonesian traffic sign by using the Criminisi or Hung method adaptation.

Figure 3. Removal of the barrier mask on the warning sign; (a) original image (b) pole mask (c) result of Criminisi method adaptation (d) result of Hung method adaptation.

Figure 4. Removal of the barrier pole on the warning sign; (a) original image (b) pole mask (c) result of Criminisi method adaptation (d) result of Hung method adaptation.

Figure 5. Removal of the barrier mask on the mandatory sign; (a) original image (b) pole mask (c) result of Criminisi method adaptation (d) result of Hung method adaptation.

Figure 3 shows the removal of the barrier mask on the warning signs, with a mask of 10% from the instructions for traffic signs, both methods are able to reconstruct the image of a traffic sign, but the adaptation of the Criminisi method has a slight black spot on the left side of the traffic sign image. Figure 4 shows the removal of the barrier mask on the warning signs, with a mask of 45% from the instructions for traffic signs, both methods can adequately reconstruct images of traffic signs, but both methods have
problems on the right and left sides of the traffic sign image, but the adaptation Hung method is more applicable. Figure 5 shows the removal of the barrier mask on the mandatory signs, with a mask of 50% from the instructions for traffic signs, both methods can reconstruct images of traffic signs adequately, but both methods have problems on the right, left and part of the instructions for traffic signs image, but the adaptation Hung method is more applicable.

Table 2. PSNR values comparison for Indonesian traffic signs with both methods.

| Image          | Size     | MSE Mask | PSNR Criminisi method adaptation | PSNR Hung method adaptation |
|----------------|----------|----------|----------------------------------|-----------------------------|
| Warning sign   | 400 x 407| 1474,834 | 36,479                           | 36,827                      |
| Warning sign   | 400 x 407| 4311,272 | 20,989                           | 21,821                      |
| Mandatory sign | 176 x 204| 5332,292 | 22,724                           | 25,258                      |

From several images for the Indonesian traffic signs Table 2, shows the average of PSNR value of the adaptation criminisi method is smaller than the adaptation hung method, it means that the Hung method was more applicable than Criminisi method.

5. Conclusion
The experiment of the proposed systems has been done. The datasets and the simulation results have been analyzed by using Hung method and Criminisi method adaptation. The reconstruction of the image of the Indonesian traffic signs have been achieved with the image size of 400 x 407 pixels. When the images are masked by 10%, the PSNR of criminisi methods and hung methods are 36,479 dB and 36,827 dB, respectively. Then, when the images are masked by 45%, the PSNR of criminisi methods and hung methods are 20,989 dB and 21,821 dB respectively. It means that the Hung method was more applicable than Criminisi method.

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