ICSITech

IEEE INDONESIA SECTION

PROCEEDINGS

2017 3rd International Conference on Science in Information Technology (ICSITech)

"Theory and Application of IT for Education, Industry and Society in Big Data Era"

Universitas Pendidikan Indonesia
Department of Computer Science Education
Bandung, Indonesia, October 25-26, 2017

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PROCEEDING

2017 3rd International Conference on Science in Information Technology (ICSITech)

"Theory and Application of IT for Education, Industry, and Society in Big Data Era"

October 25-26, 2017
Bandung, Indonesia

Editors' Preface

International Conference on Science in Information Technology (ICSITech) has been started since 2015. In the 3rd ICSITech on October 25-26, 2017, it was hosted by Universitas Pendidikan Indonesia (UPI) together with Universitas Ahmad Dahlan, Universitas Mulawarman, UPN "Veteran" Yogyakarta, Universitas Muhammadiyah Surakarta, UTM Big Data Centre, Universiti Teknologi Malaysia, Universiti Putra Malaysia, Universiti Malaysia Sabah, and Universitas Budi Luhur.

The theme of ICSITech 2017 is "Theory and Application of IT for Education, Industry, and Society in Big Data Era". It was inspired by UPI's vision and mission, which is to be leading and outstanding in education, science, technology, art, and social. Additionally, this theme can be extended into the following scope of topics:

- Big Data and Data Mining
- Decision Support System
- E-Business
- Green Software Development
- Human Computer Interaction
- Information System
- IT for Chemical
- Natural Language Processing
- Semantic Web
- Software Engineering
- Wireless Communication
- Distributed System
- Cloud & Grid Computing
- DNA Computing
- E-Learning
- Green Computing
- Image Processing & Computer Vision
- IT for Education
- Agent System and Multi-Agent Systems
- Mechatronics
- Network & Data Communication
- Social Networking & Application
- Software Entrepreneurship
- Smart City
- Electrical Engineering
- Cryptography
- E-Government
- Embedded System
- Green Information Technology
- Informatics Theory
- IT for Industry
- Mobile Computing Processing
- Open Source System
- Soft Computing
- Web Engineering
- IT for Society
- Analysis & Design of Information System
- Artificial Intelligence

After going through very rigorous review processes, there are 134 of 340 articles that have been accepted, presented, and submitted into IEEE Xplore. It means that the ratio is around 39.4%. Moreover, the articles were submitted from over 12 countries, such as Indonesia, Australia, Colombia, Japan, Nigeria, Sweden, etc. Finally, we hope this conference can improve our knowledge and be useful for us.

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2017 3rd ICSITech Schedule

Day 1: Wednesday, October 25, 2017

07.00 – 07.30	Hospitality & Registration Desks Open
07.30 – 08.30	Opening Ceremony: 1. National Anthem – Indonesia Raya 2. Culture Performance 3. Welcome Address – ICSITech 2017 Chairperson 4. Supporting Address – IEEE Indonesia Section 5. Welcome Address – Rector of Universitas Pendidikan Indonesia
08.30 – 09.00	Coffee Break
09.00 – 10.20	Keynote Speaker 1 – Tsukasa Hirashima Keynote Speaker 2 – Halimah Badioze Zaman
10.20 – 12.00	Keynote Speaker 3 – Abdurrazag Ali Aburas Keynote Speaker 4 – Dwi Hendratmo
12.00 – 13.00	Lunch and Prayer Time
13.00 – 15.00	Parallel Session 1 (presented by 72 speaker)
15.00 – 15.20	Coffee Break
15.20 – 17.40	Parallel Session 2 (presented by 84 speaker)
17.40 – 18.30	Break
18.30 – 19.00	Invitation to ICSITech 2018
19.00 – 19.15	Best Paper & Best Moderator
19.15 – 19.30	MoU Signing Ceremony
19.30 – 19.45	Closing Ceremony
19.45 – 20.00	Miscellaneous Information
20.00 – 21.30	Gala Dinner

Day 2: Thursday, October 26, 2017

07.30 – 08.30	City Tour Registration
08.30 – 12.30	City Tour (Dusun Bambu and Cihampelas Walk)
12.30 – 13.30	Back to Hotels

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Depth Inpainting Scheme Based on Edge Guided Non Local Means

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***Abstract*—The acquisition process of depth image usually produces noise and holes. This kind of defect can reduce the quality of depth image especially the existence of small or large holes which cause great loss of depth information. In this research, the depth inpainting scheme based on edge guided non local means is proposed to restore the missing depth information. Non local means (NL-means) uses similar patches within search window to recover the missing depth pixel by averaging the weighted Euclidean distance from the similar patches. The inpainting scheme iterates through boundaries of missing depth pixels. Depth image edges will act as guidance to limit the search region by using Breadth First Search (BFS). The distance calculation is performed on valid depth pixels and ignore the missing depth parts from both patches to avoid false depth information. The experiment on the depth image dataset shows that the proposed scheme can fill small to large holes on depth image with low MSE value.**

Keywords*—*depth inpainting; depth enhancement; hole filling; non local means; edge detection

I. Introduction

Depth information is a measurement of distance between object and camera/sensor. It can be acquired using depth sensor such as Kinect, time-of-flight camera, and LIDAR (Light Detection and Ranging). Depth image can be used in navigation, mapping, tracking, segmentation, and scene understanding. During the acquisition, depth image usually suffers from noise and has missing depth region due to the interference of noise or range limitation of sensor. This kind of defect can reduce the quality and make great loss of depth information.

Damaged or noisy depth image can be restored using depth image enhancement methods. One of them is depth inpainting which is a term for depth image restoration that specifically restores missing depth region. For the depth image restoration, many depth inpainting methods have been proposed. Most of them utilize both of depth and color image [1-5]. The color information is used to extract texture image and repair the missing depth edge to restore the missing depth pixels. The similarity of depth pixels, refined depth edges, and geometrical distance have influenced in the restoration process of missing depth pixels [4].

Reference [1] proposed a texture combined inpainting algorithm to repair depth image captured by Kinect. The color characteristic texture image used to repair the foreground of depth map. Weighted matched region obtained from region growing and texture information was used to fill the holes and Gaussian filter to remove noise. The test showed that the proposed method can repair the holes accurately and smooth the depth map.

Kinect depth map restoration method using modified exemplar-based inpainting has proposed by combining exemplar-based inpainting and adaptive median filtering to determine the correlation between color and depth values in local image neighborhood [2]. The result showed effectiveness on inpainting small to large holes.

Reference [3] proposed depth inpainting based on the fast marching method (FMM) by using propagation strategy of FMM and incorporate color information for depth inpainting. The experiment showed better performance than the local methods in term both visual and metric qualities.

The fusion based inpainting method that combine both color and depth information has proposed by utilizing non-local filtering accompanied with structure-guided fusion [4]. The weighting function consist of geometrical distance, depth similarity and the structure information provided by the color image. The experiment showed that the proposed method produces very reliable result.

Another finding has proposed Kinect depth restoration via energy minimization with TV_{21} regularization [5]. Energy minimization used to fill the missing regions and to remove noise in a depth map. The proposed method exploits strong correlation between color and depth in local image neighborhood. To preserve sharp edges and remove noise, they utilized TV_{21} regularization. The result showed that the method outperforms commonly-used depth inpainting methods.

This research proposes a method to restore missing depth pixels using edge guided non local means. In summary, the contribution of this work is given as follow:

a. The proposed method iterates through missing depth boundaries in order to utilize as many as possible valid depth pixels in the restoration scheme.
b. The edges are extracted from depth image by applying Laplacian of Gaussian filter with zero-crossing method.
c. In non-local means (NL-means) weight calculation, depth image edge acts as guidance for Breadth First Search (BFS) to search similar patches within search window,

spatial weighting function which represents the geometrical distance is applied, and the missing depth parts from both patches are ignored during computation to avoid false depth information.

d. Finally, the result of NL-means is used to update the missing depth pixels and the procedure iterates until all missing depth pixels are restored.

The rest of this paper is organized as Section 2 presents the proposed depth inpainting scheme, Section 3 presents the results and discussion, and the conclusion of this work is described in Section 4.

II. Methodology

A. Non Local Means (NL-means)

Non local means (NL-means) is a method originally for image denoising which uses neighborhood filter within search window to restore the damaged pixel [6]. Neighborhood filter is any filter which restores a pixel by taking an average of the values of neighboring pixels with a similar grey level value. If given a noisy image $v = \{v(i) | i \in I\}$, then the NL value can be calculated using (1).

$$NL[v](i) = \sum_{j \in I} w(i,j) v(j) \tag{1}$$

where $\{w(i,j)\}_j$ is the weights which depend on the similarity between pixels i and j, ranged from $0 \leq w(i,j) \leq 1$, and $\sum_j w(i,j) = 1$. The weights can be calculated as Euclidean distance function as shown in (2).

$$w(i,j) = \frac{1}{Z(i)} e^{-\frac{\left\| v(\mathcal{N}_i) - v(\mathcal{N}_j) \right\|_{2,a}^2}{h^2}} \tag{2}$$

Where $v(\mathcal{N}_i)$ and $v(\mathcal{N}_j)$ is the vector of square neighborhood of fixed size, $a > 0$ is standard deviation of the Gaussian kernel, h is the degree of filtering, and $Z(i)$ is the normalizing constant as shown in (3).

$$Z(i) = \sum_j e^{-\frac{\left\| v(\mathcal{N}_i) - v(\mathcal{N}_j) \right\|_{2,a}^2}{h^2}} \tag{3}$$

NL-means method make pixels which has similar grey level neighborhood have larger weights. Parameter h will control the decay of exponential function and the weights as well. The similarity not only compare the distance between two pixels but also the geometrical configuration in the neighborhood.

B. Depth Inpainting Scheme

In this research, depth inpainting based on edge guided NL-means is proposed to restore the missing depth pixels on depth image. The general procedure of the proposed depth inpainting scheme is shown in Fig. 1.

From Fig. 1, the proposed depth inpainting scheme mainly consists of iteration procedure. The proposed method iterates through missing depth pixels boundaries and restore the missing depth pixels based on edge-guided NL-means result.

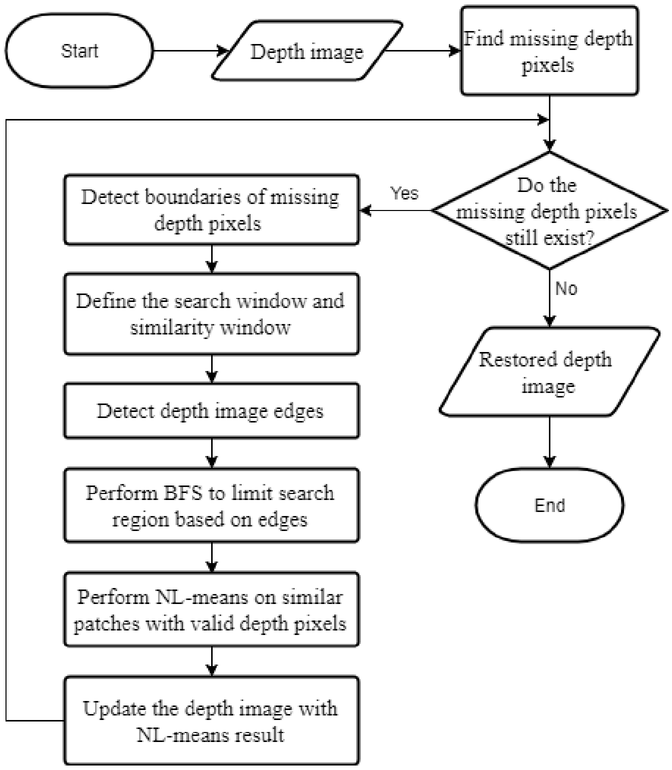


Fig. 1. General procedure of proposed depth inpainting scheme.

The proposed method is explained in the following steps.

1. Create a mask that indicates the missing depth pixel using (4). The mask will be used in the boundaries detection and acts as stopping criteria because the sum will be zero if all missing depth pixels are restored.

$$mask(i,j) = \begin{cases} 0, & I(i,j) = valid\ depth\ pixel \\ 1, & I(i,j) = missing\ depth\ pixel \end{cases} \tag{4}$$

2. Apply 1x3 and 3x1 erosion kernel as shown in Fig. 2 on the mask to find the missing pixels boundaries. The output value is the minimum value of all the pixels in the input pixel's neighborhood. If the output of either erosion application is 0 then the location is the boundaries of missing pixels.

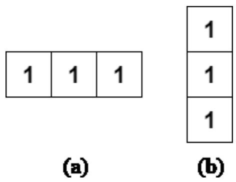


Fig. 2. Erosion kernel (a) horizontal (b) vertical

3. The restoration of missing depth pixels follows the boundaries from step 2 (filled with orange marker) as shown in Fig. 3. This procedure ensure that NL-means will calculate the similarity using as many as possible of valid depth pixels around the missing depth pixel.

4. Define the similarity window and search window around the missing depth pixel. Fig. 3 illustrates the 3x3 similarity window (marked by green rectangle) and 7x7 search window (marked by blue rectangle). Both of the windows are applied on one of the pixel (marked by red rectangle) in the missing depth boundaries.
5. Detect the edge of depth image by applying Laplacian of Gaussian (LoG) filter in (5) using zero-crossing method where x, y are the index of filter kernel and σ is the Gaussian standard deviation. In edge detection step, the false edges caused by missing depth pixels are removed and the valid edges are kept.

$$LoG(x,y) = \frac{(x^2+y^2-2\sigma^2)e^{\frac{-(x^2+y^2)}{2\sigma^2}}}{2\pi\sigma^6 \sum_x \sum_y e^{\frac{-(x^2+y^2)}{2\sigma^2}}} \quad (5)$$

6. Assume that different region is separated by edges and different region has different pixel values. Therefore, NL-means should search the similar patches inside the same region with the missing depth pixel. We use Breadth First Search (BFS) which guided by edges to search similar patches in the same region with the missing depth pixel. BFS is a search algorithm which explores its neighborhood and gives index of order then process the search according to the order. When the search hits edges, it will stop then continue the search on another available path.
7. Calculate NL-means to restore the missing depth pixels. NL-means uses similar patches within search window selected by step 6 to restore the missing depth pixel by averaging the weighted Euclidean distance from the similar patches. The missing depth parts (grey marker) from both of patches (marked in yellow and green rectangles) are ignored in the calculation of weights as shown in Fig. 3.

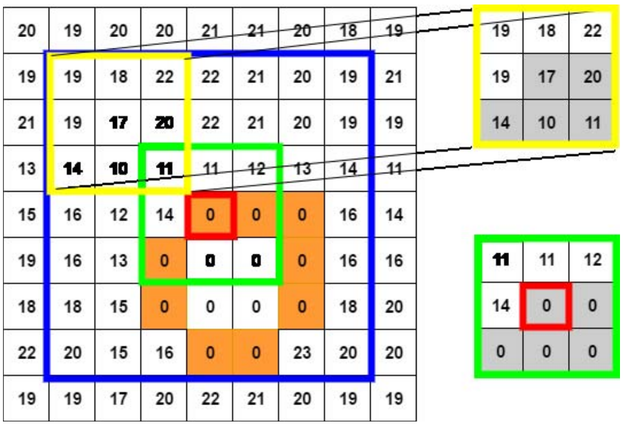


Fig. 3. Illustration of similarity window and search window and missing depth pixels that ignored in the weights calculation

8. Update the missing depth pixel with the NL-means result and update the mask.
9. If the missing pixels are existed, repeat step 2 to 8. The iteration will stop if all missing depth pixels are restored.

III. Result and Discussion

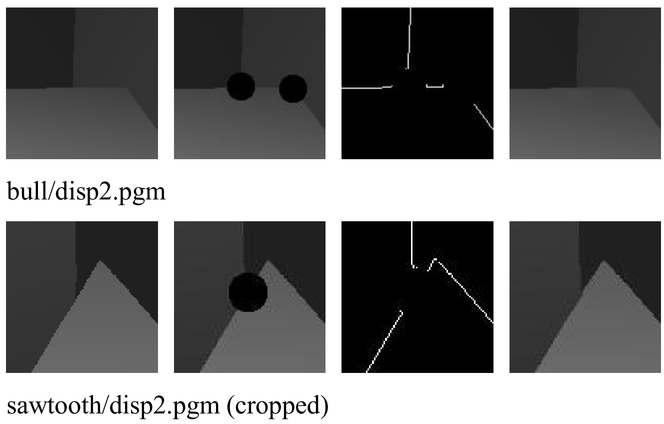
We test the performance of the proposed method on depth images from Middlebury Stereo Datasets 2001 which used in [7] and 2005 which used in [8]. The proposed method is compared with original Total Variation (TV) model used in [9]. The parameters for proposed depth inpainting based on edge guided NL-means in this experiment are 7x7 similarity window, 21x21 search window, Gaussian standard deviation $\sigma = \sqrt{2}$, and similarity penalty $h = 2\sigma$.

A. Depth Image Restoration Result

The difficulty in depth image restoration is keeping the shape of the edges. The restored pixels should maintain continuity between its neighborhood. Therefore, we test the proposed method in a condition where the holes damage the edges.

In Fig. 4, we test the restoration of missing edges. Fig.4a shows the original depth image cropped from disparity map bull/disp2.pgm (top) and cropped sawtooth/disp2.pgm (bottom). We remove some area at the edges as shown in Fig.4b. The initial edge detection result is shown in Fig.4c and the restoration result is shown in Fig.4d. The restoration produces 0.1941 of MSE for bull/disp2.pgm and 3.6578 of MSE for sawtooth/disp2.pgm.

As shown in Fig.4d, the proposed method can restore the depth pixels with low MSE and keep the shape of the edges although a part of the edge is little blurred. The blurring effect while performing depth inpainting using edge-guided NL-means is controlled by the penalty parameter h. The blurred edges can be sharpening further by repeating the proposed depth inpainting scheme.



(a) (b) (c) (d)

Fig. 4. Edges restoration result (a) original depth image (b) damaged depth image (c) edges of depth image (d) restoration result

In Fig. 5, the proposed method is tested to restore missing depth pixels produced during depth acquisition. The depth images are taken from Middlebury Stereo Datasets 2005. Fig. 5a shows the original depth images and Fig. 5b shows the restoration results. From Fig. 5a, the depth image suffers from missing depth pixels.

The missing depth pixels produced during depth acquisition usually located at the edges. Therefore, in Fig.4, we show that the proposed method capable to restore depth pixels and maintain the shape of the edges.

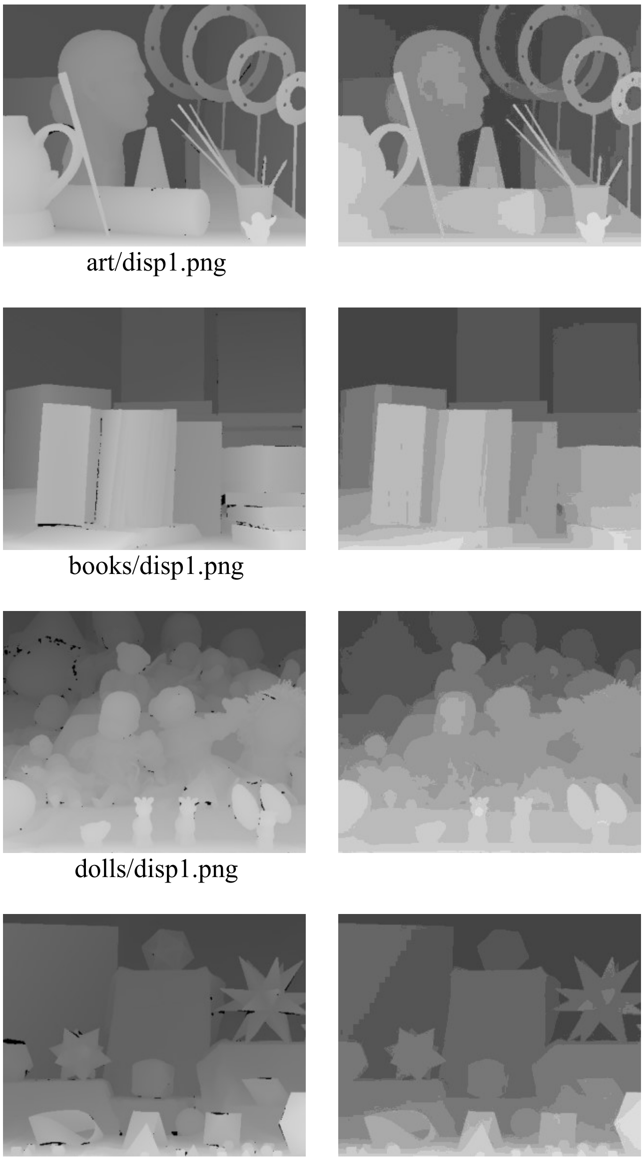
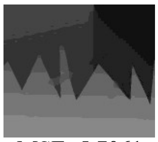
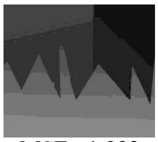
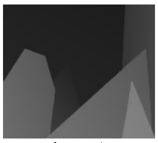
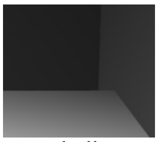
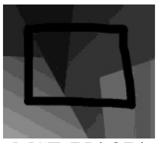
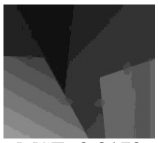


Fig. 5. Implementation of proposed method on Middlebury Stereo Datasets 2005 (a) original depth images (b) restored depth images

B. Performance Comparison

We compare the performance of our method with TV inpainting model based on [9] on depth images taken from Middlebury Stereo Datasets 2001 and choose the disp2.pgm files as shown in Table I. The TV inpainting uses random noise in the initialization process and fidelity weight $\lambda = 0.5$ with 10,000 iteration. Table I shows that the proposed method performs better in restoring damaged depth image with relatively low MSE than TV inpainting.

TABLE I. DEPTH INPAINTING PERFORMANCE COMPARISON

Original depth image	Damaged depth image	TV Inpainting	Proposed method
 sawtooth	 MSE: 346.046	 MSE: 5.7061	 MSE: 1.992
 barn1	 MSE: 652.586	 MSE: 4.3239	 MSE: 1.425
 bull	 MSE:375.201	 MSE: 2.6346	 MSE:0.348
 venus	 MSE:754.974	 MSE: 2.8172	 MSE:0.700

In order to lower the MSE and smooth the depth image, the proposed depth inpainting scheme can be repeated and the procedure will become image denoising using edge guided NL-means because all the holes in depth image already restored.

IV. CONCLUSION

In this research, a depth inpainting scheme based on edge guided non local means is proposed to restore damaged depth image. The proposed method iterates through missing depth pixel boundaries in order to utilize as many as possible valid depth pixels. At the NL-means weight calculation, the depth image edges act as guidance to limit the search region within search window. The result of NL-means using mentioned scheme is used to update the missing depth pixels until all missing depth pixels are restored. From the experiment with Middlebury Stereo Datasets, the proposed method produces low MSE value and maintain the shape of the edges although the edges a bit blurred. For future works, the proposed method can be developed to restore depth image with even lower MSE value and keep the shape of the edges sharp also utilize the color information that provided in RGB-D data.

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