Supplementary Results for Image-based 4-d Reconstruction using 3-d Change Detection

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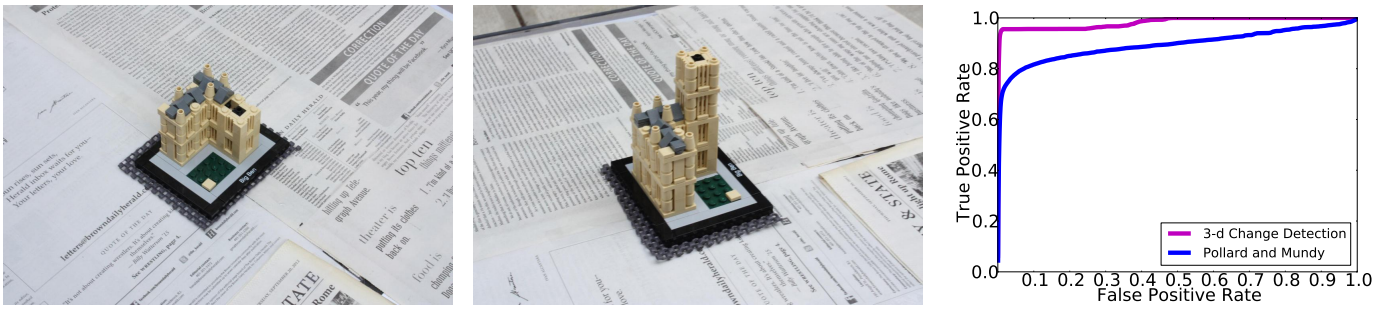
1 Comparison of the Proposed 3-d Change Detection Algorithm with Pollard and Mundy's Approach [1]

The proposed 4-d reconstruction pipeline performs 3-d change detection between the current set of images and the 3-d model from the previous time step. This change detection is facilitated by a dense 3-d model (PVM) that allows predicting image pixel intensities from arbitrary viewpoints and therefore, change detection. Please see the main text for details. This framework was first utilized by Pollard and Mundy where they use the PVM to compute the probability of change in each *pixel* of a subsequent image [1]. A contribution of this paper is to extend Pollard and Mundy's algorithm to utilize multiple viewpoints and compute the probability of change in the 3-d domain, rather than the image domain. This section presents a comparison of the proposed approach with Pollard and Mundy's algorithm to demonstrate the benefits of utilizing multiple viewpoints and 3-d change reasoning. However, the results cannot be directly compared since Pollard and Mundy's algorithm detects pixel-wise changes, whereas the proposed algorithm estimates the volumetric structure of change. The results can be compared by projecting the 3-d changes computed by the proposed algorithm onto the image domain. Ground truth changes on test images were manually labeled and used to compute ROC curves for quantitative comparison.

Comparisons using the Big Ben dataset are presented first. The dataset captures the incremental construction of a Lego Big Ben tower in a total of six time steps. For this experiment, the third and the fourth time steps are used. Example images are shown in Figure 1. The two blocks added on top of the tower constitute the changes between the two time steps. Figure 1c displays the ROC curves comparing the two approaches. The proposed approach outperforms the results of [1]. These curves were constructed by averaging detection results from five images (see top row of Figure 2). Changes computed by Pollard and Mundy's approach and the proposed algorithm are shown in Figure 2 middle and bottom rows respectively. It can be observed that the results of the proposed approach contain less false positives.

The second set of results are using the plastic model town dataset. For this experiment, the first and second time steps are used. Example images are shown in Figure 3. The toy cars



(a) (b) (c)

Figure 1: Results for the Big Ben dataset. (a) Third time step. (b) Fourth time step. (c) ROC curves comparing the change detection results of the proposed algorithm with that of Pollard and Mundy [1].

that were added to the town constitute the changes between the time steps. Figure 3c displays the ROC curves comparing the two approaches. The proposed approach outperforms the results of [1]. These curves were constructed by averaging detection results from five images (see top row of Figure 2). Changes computed by Pollard and Mundy's approach and the proposed algorithm are shown in Figure 2 middle and bottom rows respectively. It can be observed that Pollard and Mundy's approach has difficulty detecting certain changes, e.g., the white car, from some viewpoints. The proposed approach yields better detection results since it utilizes information from multiple viewpoints, which leads to better ROC performance.

Figures 5 and 6 display the comparisons for the trash can dataset. The results are similar to the previous two datasets. Finally, similar results were obtained for the final dataset which was obtained from the work of Taneja et al. [2].

2 Comparison to Individually Reconstructed 3-d Models

Figure 7 displays comparisons of the proposed 4-d reconstruction method with the method of reconstructing independent 3-d models at each time step for the model town dataset. The rows provide examples for time steps 1, 2, 4 and 6, top to bottom respectively. The first and second columns display the original image and the result of the proposed method. Note the proposed method achieves high quality results comparable to the original image. The third and forth columns show renderings of 3-d models reconstructed using PMVS [3]+Poisson [4] and the PVM approach respectively. It can be observed that the reconstruction quality is significantly worse, especially for the second, fourth and sixth time steps where there are only ten images available. The results for the initial time step, where there are roughly fifty images, is better.

Static structures in the model town, that were reconstructed accurately in the initial time step, are detected as unchanging, which allows their reconstructions to persist from the initial time step to future time steps. In contrast, the method of reconstructing individual models at each time step attempts to reconstruct the entire scene structure from the sparse set of images. This approach is typically not satisfactory when the number of images available is small.

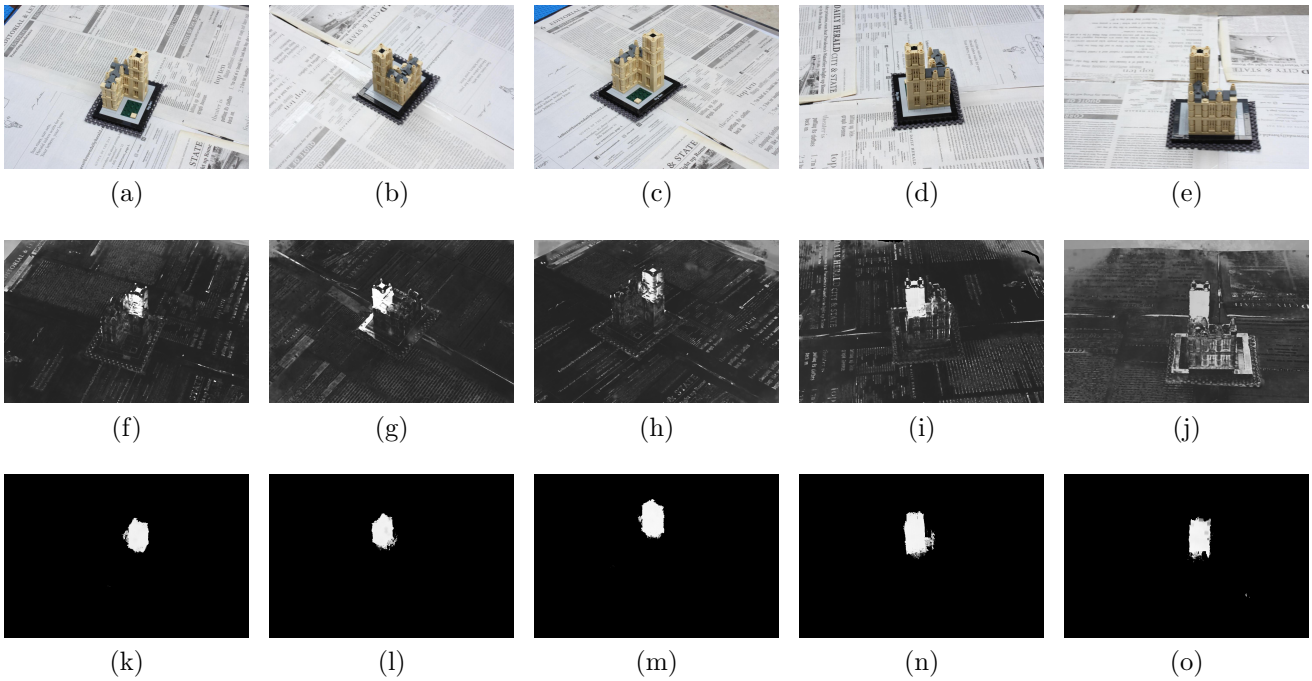


Figure 2: Results for the Big Ben dataset. First row: five images used for the experiment. Middle row: Pollard and Mundy's change detection results. Bottom row: Proposed algorithm's change detection results.

References

[1] Pollard, T., Mundy, J.L.: Change Detection in a 3-d World. In: CVPR. (June 2007)

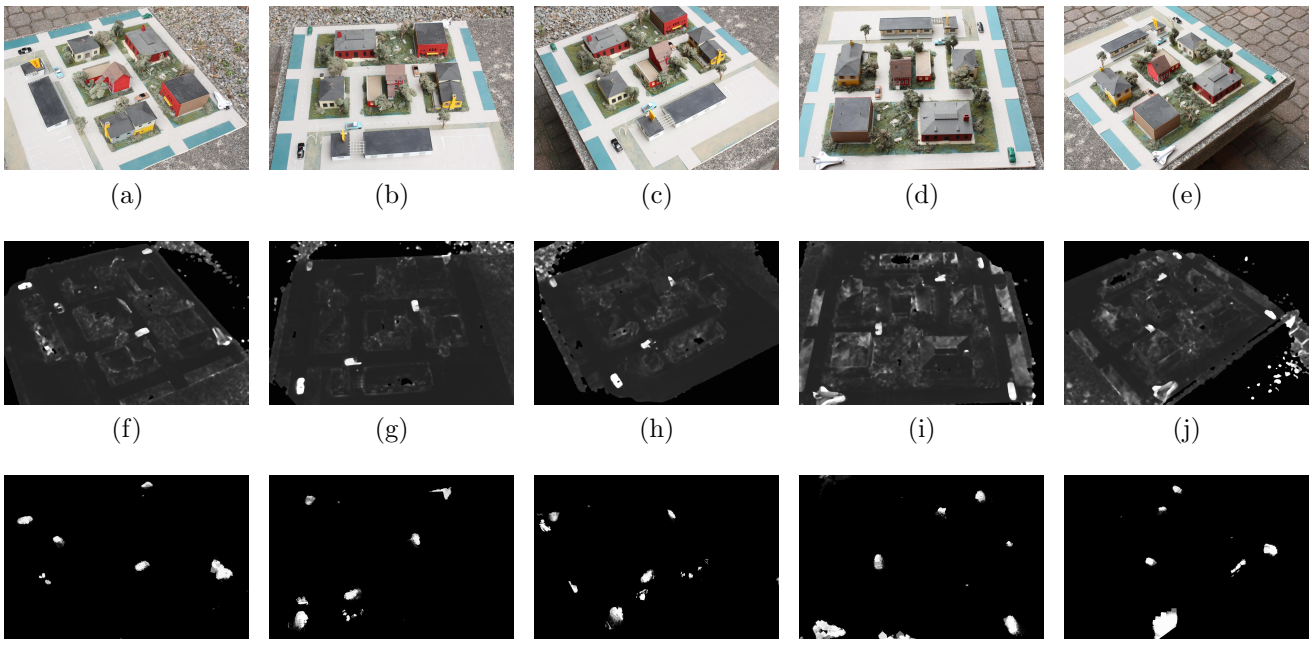
[2] Taneja, A., Ballan, L., Pollefeys, M.: Image based detection of geometric changes in urban environments. ICCV (November 2011)

[3] Furukawa, Y., Ponce, J.: Accurate, dense, and robust multiview stereopsis. PAMI (August 2010)

[4] Kazhdan, M., Bolitho, M., Hoppe, H.: Poisson surface reconstruction. Eurographics (2006)

(a) (b) (c)

Figure 3: Results for the plastic model town dataset. (a) First time step. (b) Second time step. (c) ROC curves comparing the change detection results of the proposed algorithm with that of Pollard and Mundy [1].



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

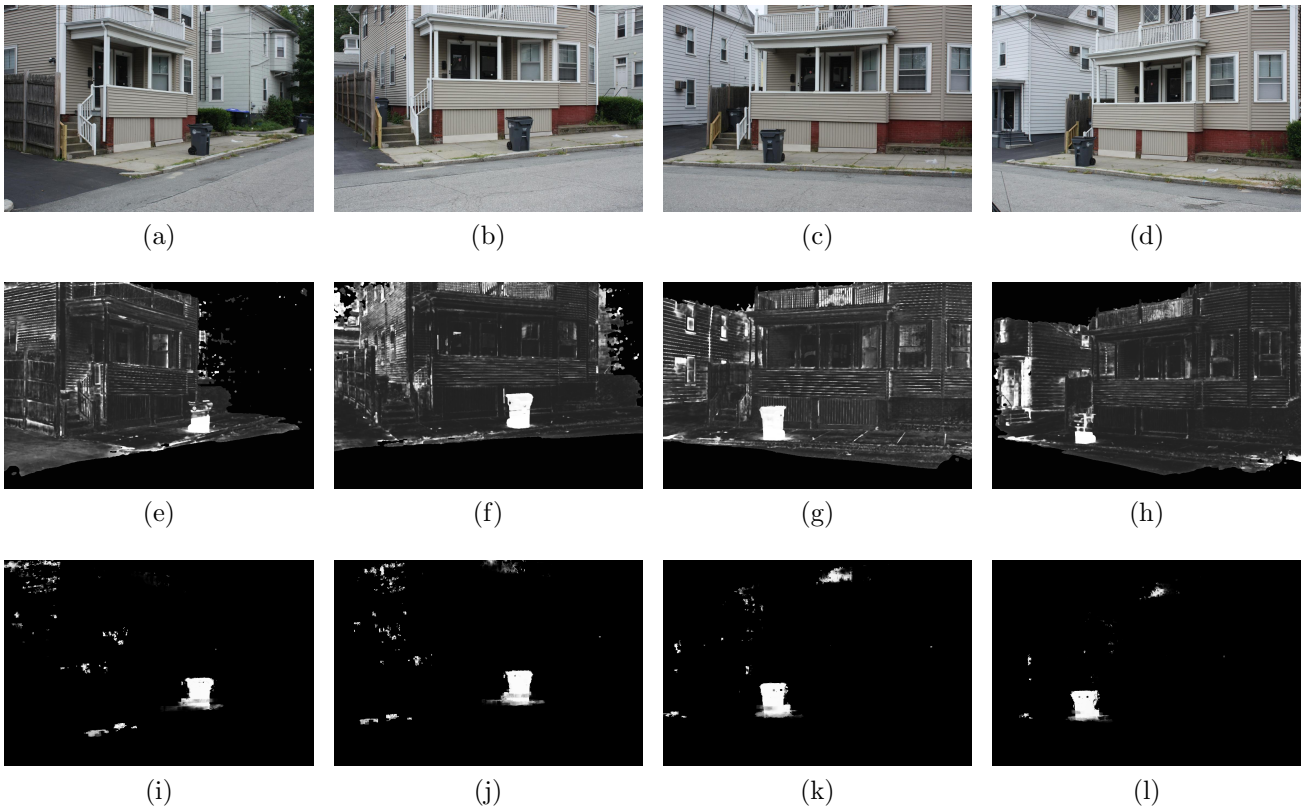
(f) (g) (h) (i) (j)

(k) (l) (m) (n) (o)

Figure 4: Results for the plastic model town dataset. (a) First time step. (b) Second time step. (c) ROC curves comparing the change detection results of the proposed algorithm with that of Pollard and Mundy [1].

(a) (b) (c)

Figure 5: Results for the trash can dataset. (a) First time step. (b) Second time step. (c) ROC curves comparing the change detection results of the proposed algorithm with that of Pollard and Mundy [1].



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

(e) (f) (g) (h)

(i) (j) (k) (l)

Figure 6: Results for the trash can dataset. First row: four images used for the experiment. Middle row: Pollard and Mundy's change detection results. Bottom row: Proposed algorithm's change detection results.

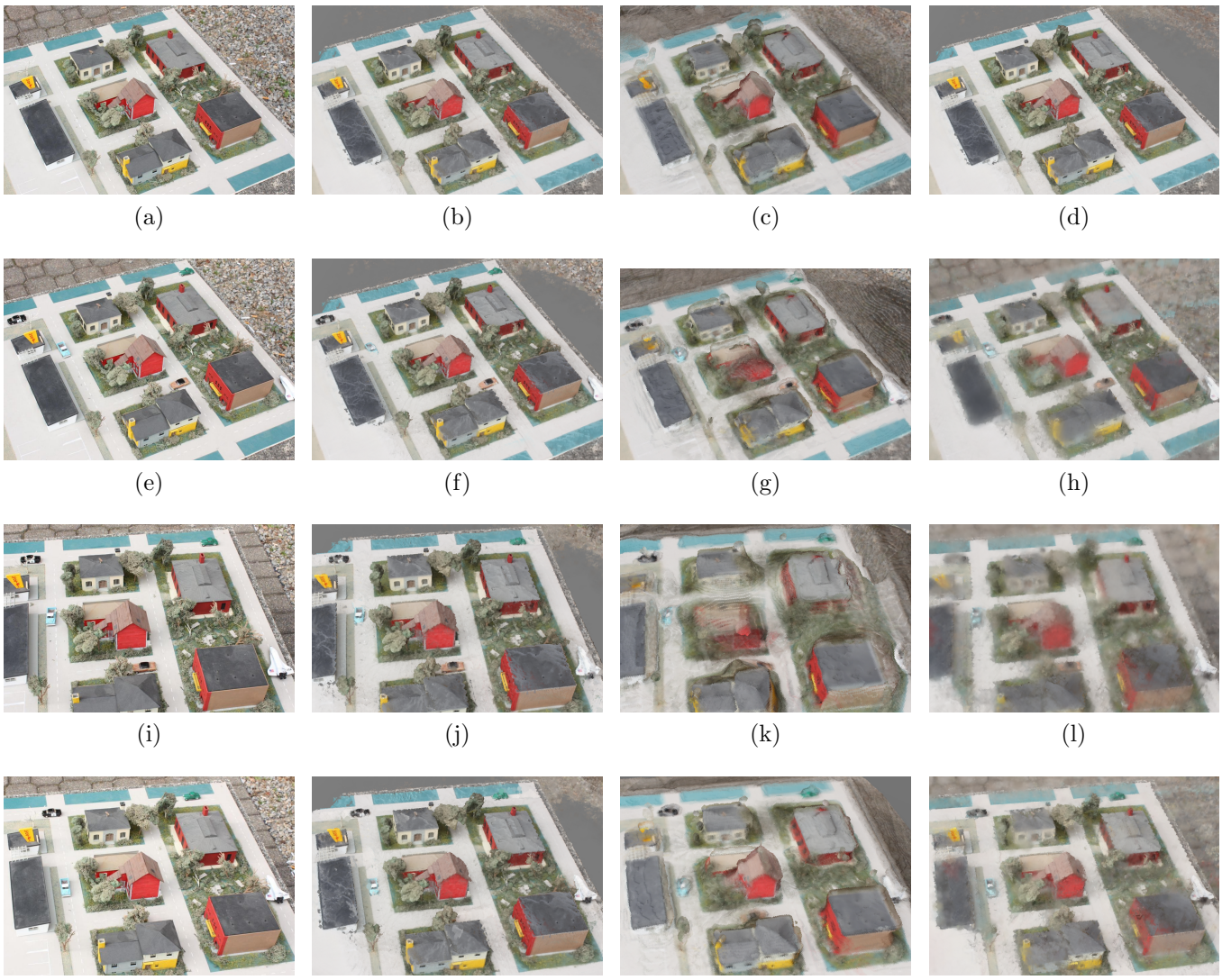


Figure 7: Comparison of the proposed 4-d reconstruction algorithm with independent reconstruction of each time step. First column: original images from time steps 0, 1, 3 and 5, top to bottom respectively. Second column: Renderings of the 4-d models produced by the proposed algorithm. Third column: Renderings of the 3-d models produced by running PMVS [3]+Poisson [4] for each time step independently, i.e., using only images captured at that time step. Fourth column: Renderings of the 3-d PVM models produced independently for each time step.