

# Supplementary Material to “Weighted Nuclear Norm Minimization with Application to Image Denoising”

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In this document, we present more denoising results which are not included in the main paper due to page limit.

## 1. More Results on the 20 Test Images

In the main paper, we have given the denoising results (PSNR) of the 20 benchmark test images on noise levels 10, 30, 50 and 100. Here we give the PSNR results on noise levels 20, 40 and 75 in Table 1.

Figure 1 shows the average PSNR indices over the 20 images on the seven noise levels. In Figures 2-11, we present more visual comparisons of the denoising outputs by the competing methods.

Table 1. Denoising results (PSNR) by different methods.

|           | $\sigma_n = 20$ |       |              |       |       |              | $\sigma_n = 40$ |       |       |       |              |              | $\sigma_n = 75$ |       |       |       |       |              |
|-----------|-----------------|-------|--------------|-------|-------|--------------|-----------------|-------|-------|-------|--------------|--------------|-----------------|-------|-------|-------|-------|--------------|
|           | BM3D            | EPLL  | LSSC         | NCSR  | SAIST | WNNM         | BM3D            | EPLL  | LSSC  | NCSR  | SAIST        | WNNM         | BM3D            | EPLL  | LSSC  | NCSR  | SAIST | WNNM         |
| C-Man     | 30.48           | 30.34 | 30.61        | 30.47 | 30.45 | <b>30.75</b> | 27.18           | 27.04 | 27.33 | 27.12 | 27.09        | <b>27.48</b> | 24.33           | 24.20 | 24.39 | 24.23 | 24.30 | <b>24.55</b> |
| House     | 33.77           | 32.98 | <b>34.11</b> | 33.87 | 33.75 | 34.04        | 30.65           | 29.88 | 31.10 | 30.80 | 31.14        | <b>31.31</b> | 27.51           | 26.68 | 27.75 | 27.22 | 28.08 | <b>28.25</b> |
| Peppers   | 31.29           | 31.16 | 31.37        | 31.19 | 31.32 | <b>31.55</b> | 27.70           | 27.73 | 27.86 | 27.68 | 27.77        | <b>28.05</b> | 24.73           | 24.56 | 24.65 | 24.36 | 24.66 | <b>24.93</b> |
| Montage   | 33.61           | 32.56 | 33.51        | 33.26 | 33.41 | <b>34.16</b> | 29.52           | 28.47 | 29.43 | 29.00 | 29.32        | <b>29.92</b> | 25.52           | 24.90 | 25.40 | 25.49 | 25.46 | <b>25.73</b> |
| Leaves    | 30.10           | 29.39 | 30.47        | 30.45 | 30.64 | <b>31.10</b> | 25.71           | 25.62 | 26.04 | 26.25 | 26.49        | <b>26.95</b> | 22.49           | 22.03 | 22.16 | 22.60 | 22.89 | <b>23.06</b> |
| Starfish  | 29.68           | 29.57 | 29.96        | 29.93 | 29.97 | <b>30.28</b> | 26.06           | 26.11 | 26.22 | 26.21 | 26.39        | <b>26.60</b> | 23.27           | 23.16 | 23.12 | 23.20 | 23.35 | <b>23.47</b> |
| Mornar.   | 30.35           | 30.48 | 30.59        | 30.62 | 30.76 | <b>31.10</b> | 26.72           | 26.89 | 26.87 | 26.85 | 27.16        | <b>27.47</b> | 23.91           | 23.72 | 23.66 | 23.67 | 23.98 | <b>24.31</b> |
| Airplane  | 29.55           | 29.67 | 29.69        | 29.58 | 29.65 | <b>29.89</b> | 26.08           | 26.29 | 26.23 | 25.96 | 26.26        | <b>26.51</b> | 23.47           | 23.35 | 23.41 | 23.18 | 23.60 | <b>23.75</b> |
| Paint     | 30.36           | 30.39 | 30.59        | 30.33 | 30.51 | <b>30.75</b> | 26.69           | 26.88 | 26.77 | 26.50 | 26.94        | <b>27.10</b> | 23.80           | 23.82 | 23.52 | 23.44 | 23.83 | <b>24.07</b> |
| JellyBean | 34.18           | 33.81 | 34.55        | 34.52 | 34.31 | <b>34.85</b> | 30.21           | 29.98 | 30.76 | 30.56 | 30.51        | <b>30.85</b> | 27.22           | 26.58 | 27.21 | 27.18 | 27.08 | <b>27.44</b> |
| Fence     | 29.93           | 29.25 | 30.07        | 30.11 | 30.16 | <b>30.37</b> | 26.84           | 25.75 | 26.89 | 26.77 | 27.01        | <b>27.32</b> | 24.22           | 22.46 | 24.04 | 23.76 | 24.26 | <b>24.68</b> |
| Parrot    | 29.96           | 29.96 | 29.95        | 29.90 | 29.97 | <b>30.19</b> | 26.69           | 26.80 | 26.75 | 26.66 | 26.88        | <b>27.10</b> | 24.19           | 24.04 | 24.01 | 23.90 | 24.17 | <b>24.37</b> |
| Lena      | 33.05           | 32.61 | 32.88        | 32.95 | 33.08 | <b>33.12</b> | 29.86           | 29.47 | 29.90 | 29.92 | 30.07        | <b>30.11</b> | 27.26           | 26.57 | 27.21 | 27.00 | 27.23 | <b>27.54</b> |
| Barbara   | 31.78           | 29.76 | 31.59        | 31.78 | 32.16 | <b>32.21</b> | 27.99           | 26.02 | 28.17 | 28.20 | 28.77        | <b>28.77</b> | 25.12           | 22.94 | 25.01 | 24.73 | 25.54 | <b>25.81</b> |
| Boat      | 30.88           | 30.66 | 30.91        | 30.79 | 30.84 | <b>31.00</b> | 27.74           | 27.64 | 27.77 | 27.65 | 27.68        | <b>27.96</b> | 25.12           | 24.89 | 25.03 | 24.87 | 24.99 | <b>25.29</b> |
| Hill      | 30.72           | 30.49 | 30.72        | 30.65 | 30.69 | <b>30.80</b> | 27.99           | 27.81 | 27.99 | 27.83 | 27.96        | <b>28.12</b> | 25.68           | 25.46 | 25.57 | 25.40 | 25.56 | <b>25.88</b> |
| F.print   | 28.81           | 28.28 | 28.78        | 28.96 | 29.01 | <b>29.02</b> | 25.30           | 24.73 | 25.30 | 25.51 | <b>25.60</b> | 25.57        | 22.83           | 21.46 | 22.55 | 22.66 | 22.88 | <b>23.02</b> |
| Man       | 30.59           | 30.63 | 30.72        | 30.59 | 30.67 | <b>30.74</b> | 27.65           | 27.63 | 27.64 | 27.54 | 27.60        | <b>27.80</b> | 25.32           | 25.14 | 25.10 | 25.10 | 25.14 | <b>25.42</b> |
| Couple    | 30.76           | 30.54 | 30.74        | 30.60 | 30.66 | <b>30.82</b> | 27.48           | 27.27 | 27.41 | 27.24 | 27.40        | <b>27.61</b> | 24.70           | 24.45 | 24.51 | 24.33 | 24.54 | <b>24.86</b> |
| Straw     | 26.98           | 26.80 | 27.17        | 27.32 | 27.42 | <b>27.44</b> | 23.05           | 23.11 | 23.56 | 23.46 | <b>23.78</b> | 23.76        | 20.56           | 19.94 | 20.71 | 20.39 | 20.90 | <b>21.00</b> |
| AVE       | 30.84           | 30.47 | 30.95        | 30.89 | 30.97 | <b>31.21</b> | 27.36           | 27.06 | 27.50 | 27.39 | 27.59        | <b>27.82</b> | 24.56           | 24.02 | 24.45 | 24.34 | 24.62 | <b>24.86</b> |

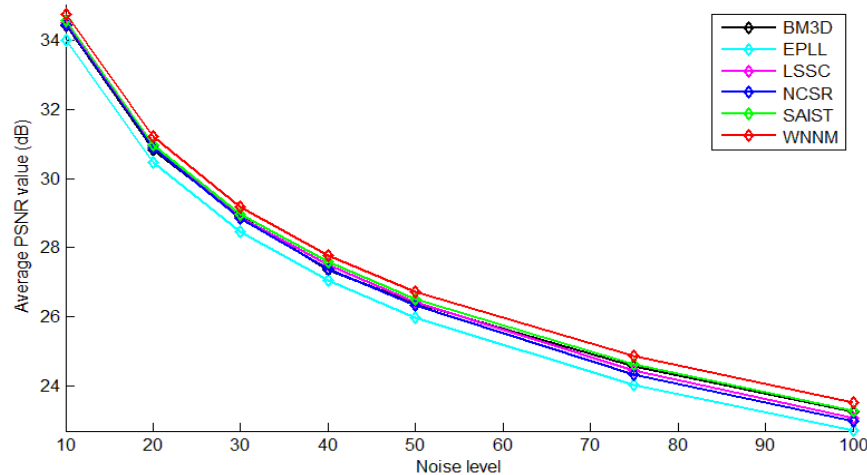


Figure 1. Average PSNR values over the 20 test images by different methods.

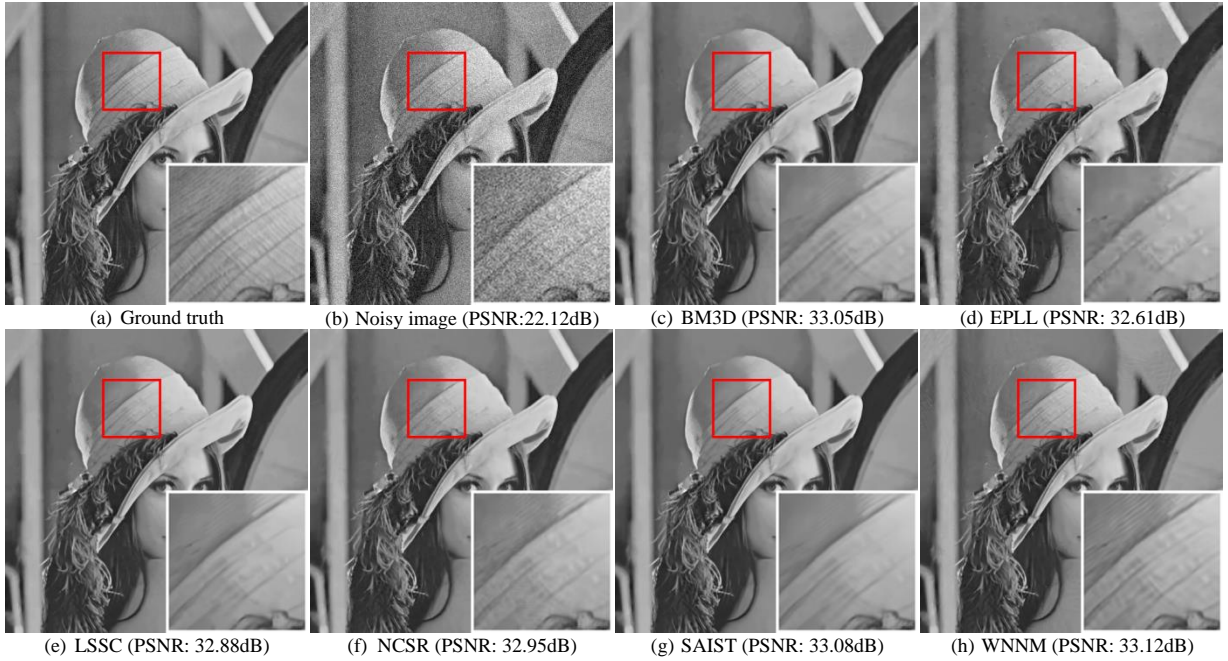


Figure 2. Denoising results on image *Lena* by different methods (noise level = 20).

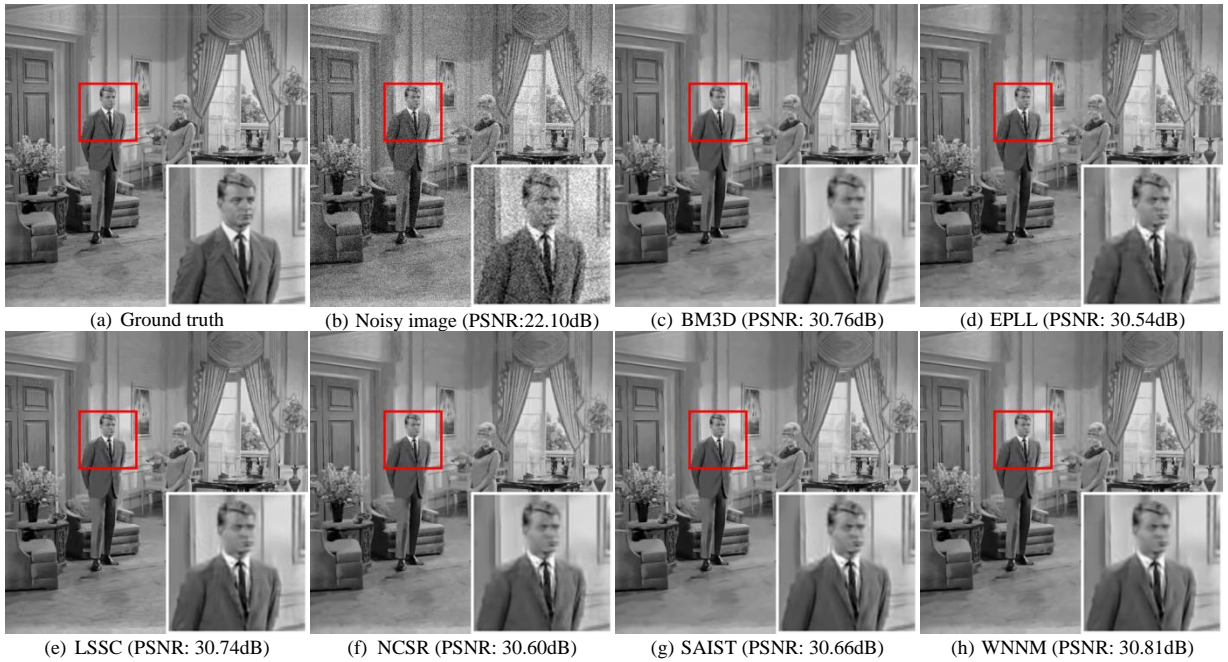


Figure 3. Denoising results on image *Couple* by different methods (noise level = 20).

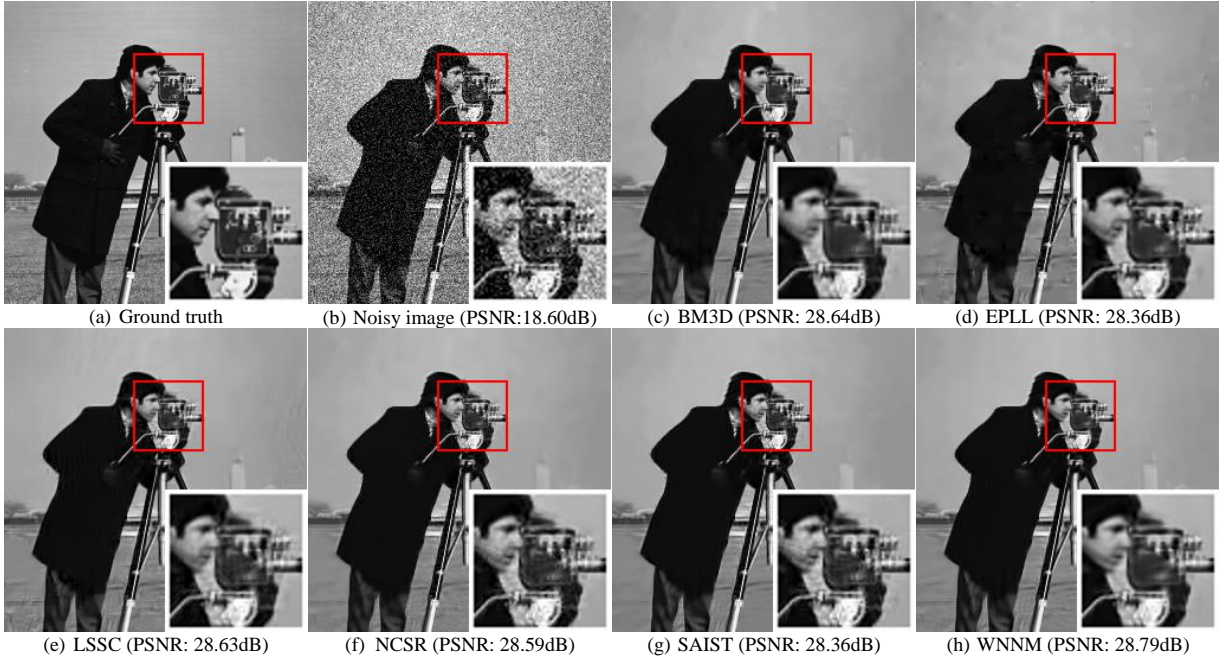


Figure 4. Denoising results on image *CameraMan* by different methods (noise level = 30).



Figure 5. Denoising results on image *Hill* by different methods (noise level = 40).



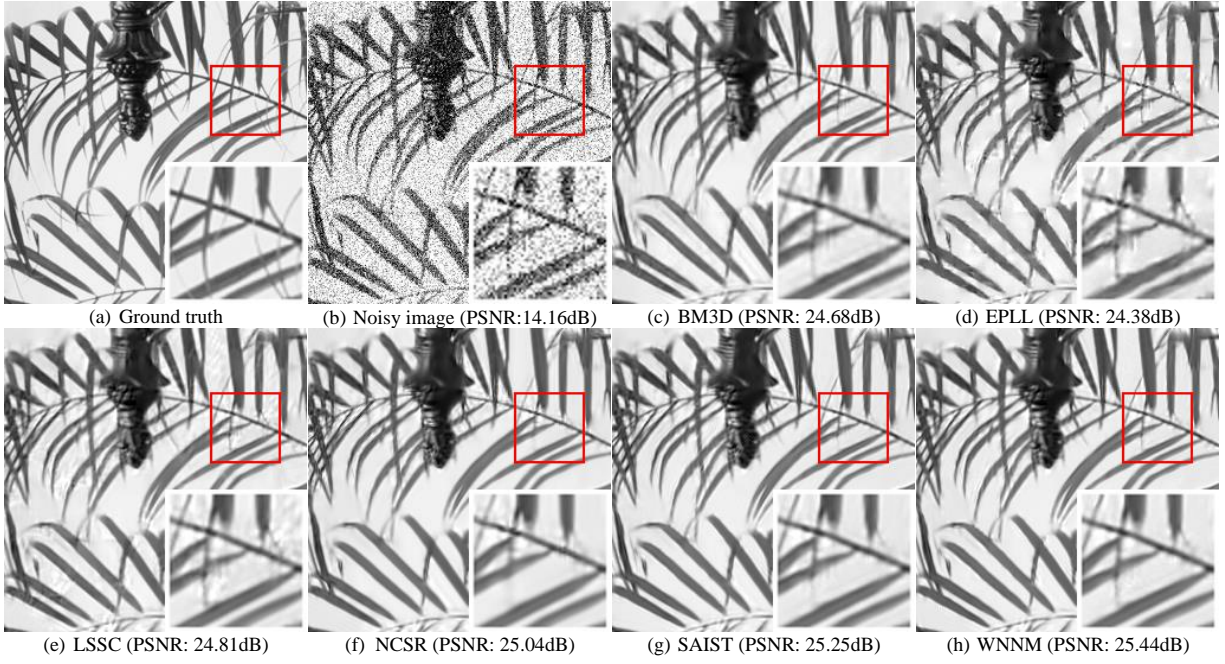


Figure 6. Denoising results on image *Leaves* by different methods (noise level = 50).

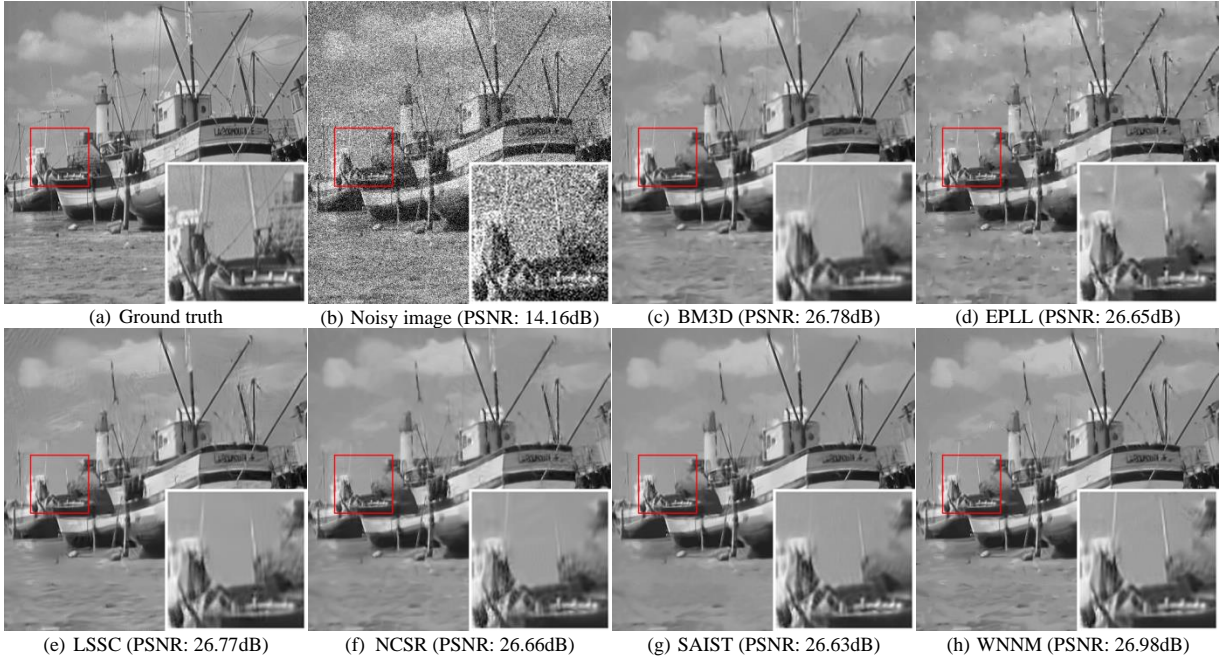


Figure 7. Denoising results on image *Boats* by different method (noise level = 50).

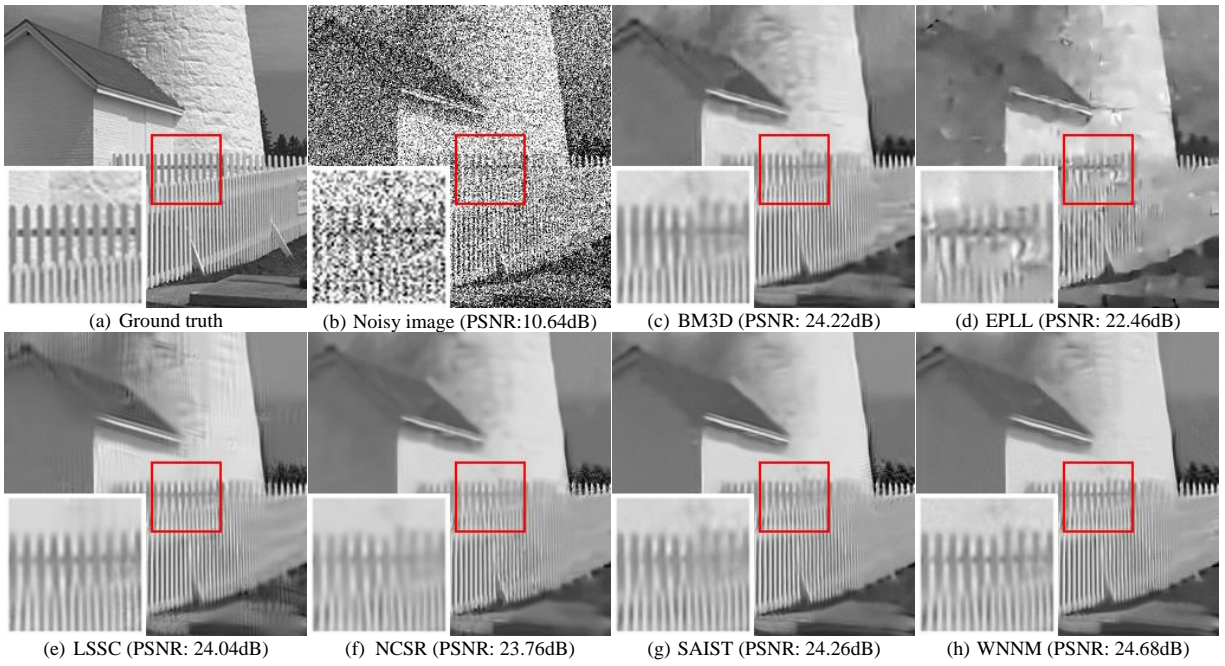


Figure 8. Denoising results on image *Fence* by different methods (noise level = 75).

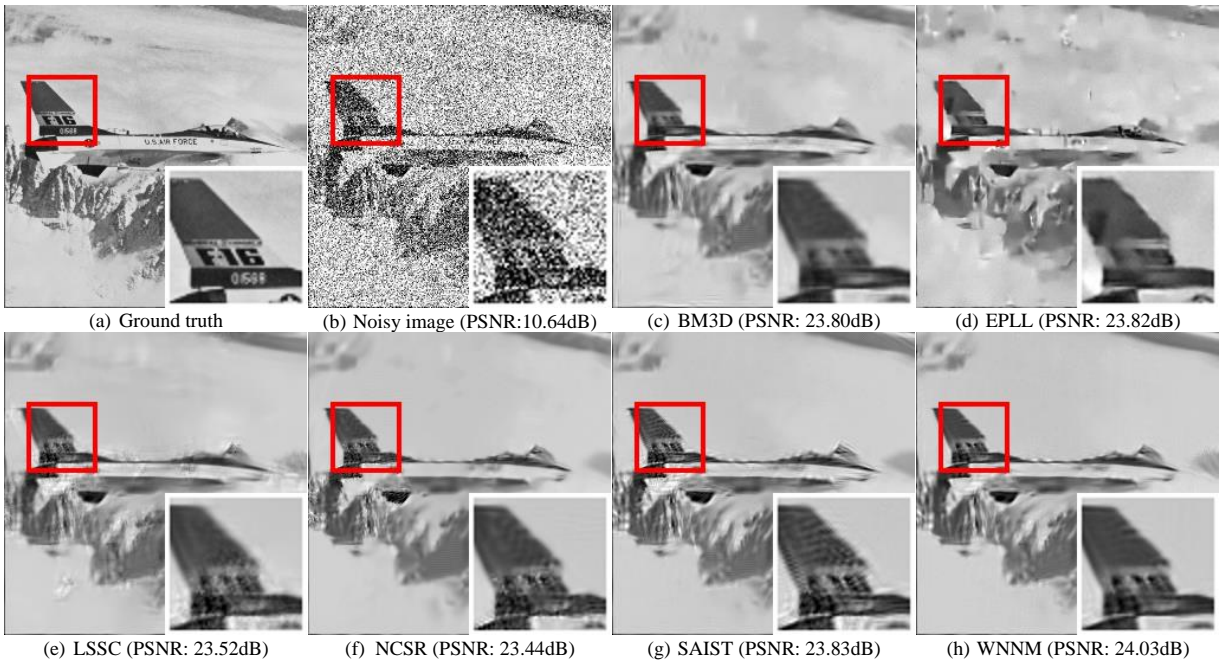


Figure 9. Denoising results on image *Fence* by different methods (noise level = 75).



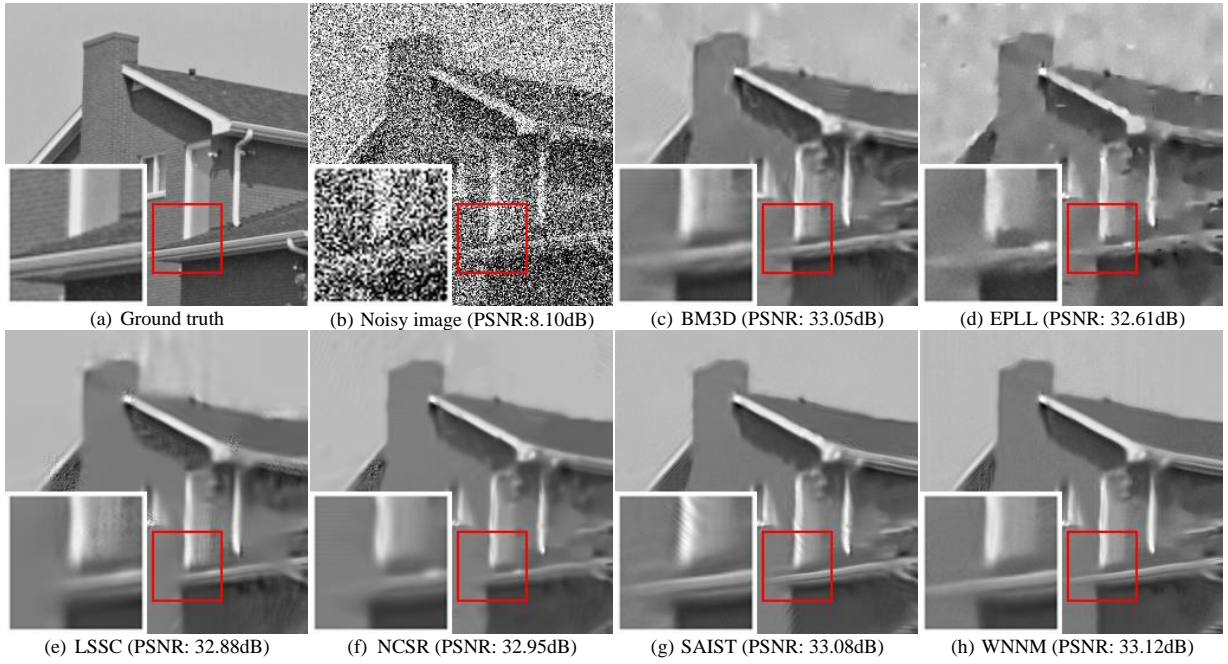


Figure 10. Denoising results on image *House* by different methods (noise level = 100).

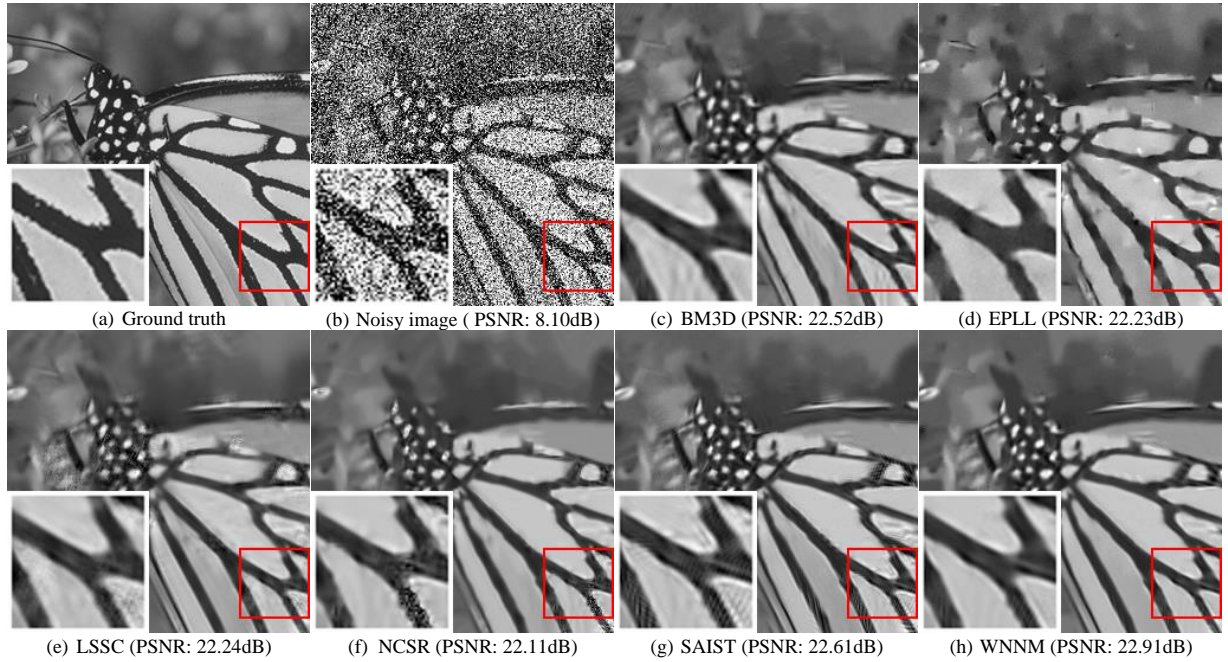


Figure 11. Denoising results on image *Monarch* by different methods (noise level = 100).