Supplemental Material: Automatic Content-aware Projection for 360° Videos

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We provide additional qualitative comparisons with stat-of-the-art projection methods on various *still images* in Sec 1 which could not be included in the main paper due to the space limitation. Furthermore, we provide the *demo video* which shows the effect of the temporal consistency of the proposed projection method. Please see our demo video.

1. Qualitative Comparison with Stat-of-the-art Projection Methods

Figure 1 to Figure 7 show the additional results of our contents-aware projection method with the results of other projection methods to compare the performance qualitatively. For clear comparison of the proposed contents-aware projection method, we collected additional 360° images from the web. We used automatically extracted line segments and salient points as inputs for Carroll's method and our projection algorithms for the fair comparison.

Overall, rectilinear projection preserves every line in images but causes stretching distortions at the borders. In stereographic projection, conformality of objects is preserved, but all the lines except radial lines are bent. Pannini projection [3] preserves vertical lines, but the horizontal lines are not well preserved in many cases. Carroll's method [1] preserves only the extracted line segments. Our optimized Pannini projection preserves horizontal lines better, but a little stretch at the borders. Our model-interpolated optimized Pannini method prevents these stretches occurred at the border of the projected images while preserving the conformality of the salient regions well — it preserves lines and conformality of salient regions simultaneously (thanks to the parameter optimization) over the whole image (thanks to model interpolation). In addition, although our method is optimization-based, our parameter optimization is very fast and takes about 1ms on a single CPU. In the figures, red arrows indicate noticeable distortions and green arrows indicate improvements by the proposed method.

2. Demo Video for Temporal Consistency Comparison

We performed the experiments on 360 ° videos with datasets collected from the web. 360 ° video were projected to a perspective video with given viewpoints per frames. Although viewpoints were estimated also automatically, its explanation is not included because it is outside our scope. Because State-of-the-art content-aware projections can not applied to videos, unfortunately, results of the algorithms were not included. We show results of the proposed framework for three datasets: Restaurant, Lego, Home. The top-left, top-right and bottom-left of the video represent spherical images, estimated saliency and projection images, respectively. Green regions in the bottom-left of the video denote the projected area. The results show that our framework works well in various environments. Especially, the results show that our framework can handle situations including viewpoint change or dynamic objects. Also, we show results to compare with temporal consistency. For results without temporal consistency, we set ω_d, ω_s, ω_{md}, ω_{ms} and ω_p to 0. The demo video will be uploaded to the site.[1]

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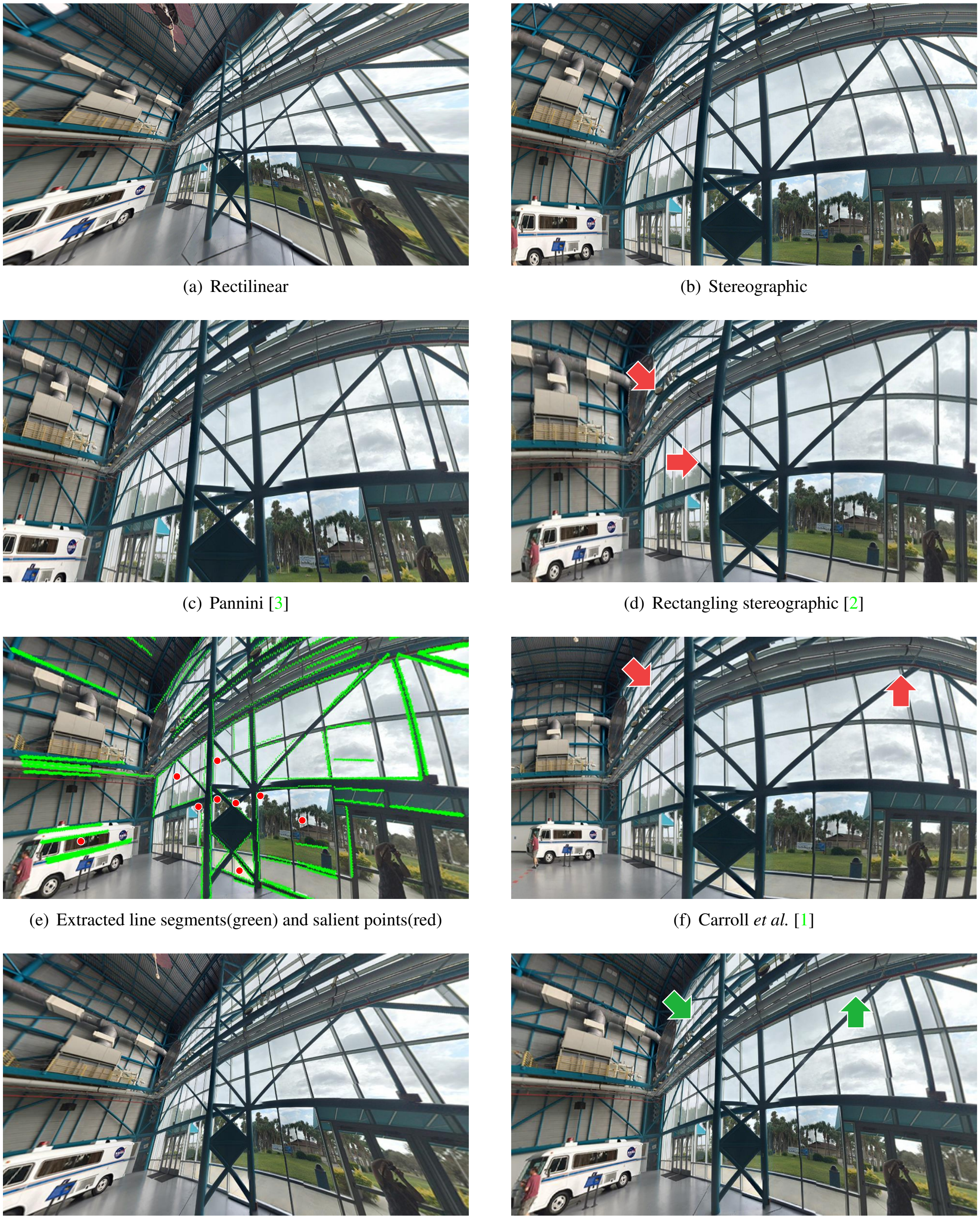
[1]https://cvl.gist.ac.kr/360projection/



(a) Rectilinear

(b) Stereographic

(c) Pannini [3]

(d) Rectangling stereographic [2]

(e) Extracted line segments(green) and salient points(red)

(f) Carroll *et al.* [1]

(g) Our result - optimized Pannini

(h) Our result - model interpolation

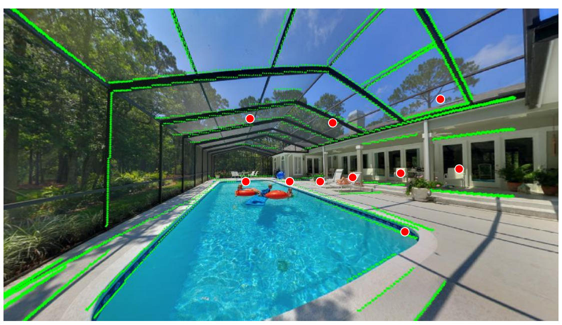
Figure 1. Carroll's method (f) is hard to preserve every linear structure because the line segments are fragmented. Rectangling stereographic (d) bends the linear structures on diagonal regions (red arrows). On the other hand, our algorithm (h) relatively well preserves the linear structures (green arrows).

(a) Rectilinear

(b) Stereographic

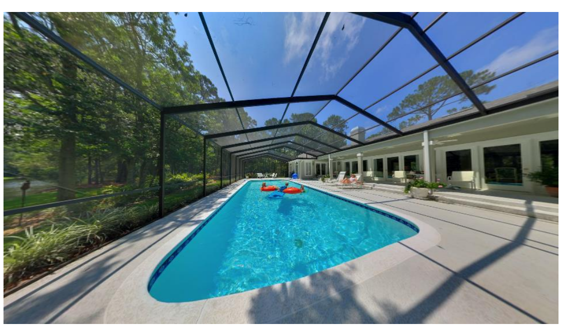
(c) Pannini [3]

(d) Rectangling stereographic [2]



(e) Extracted line segments(green) and salient points(red)

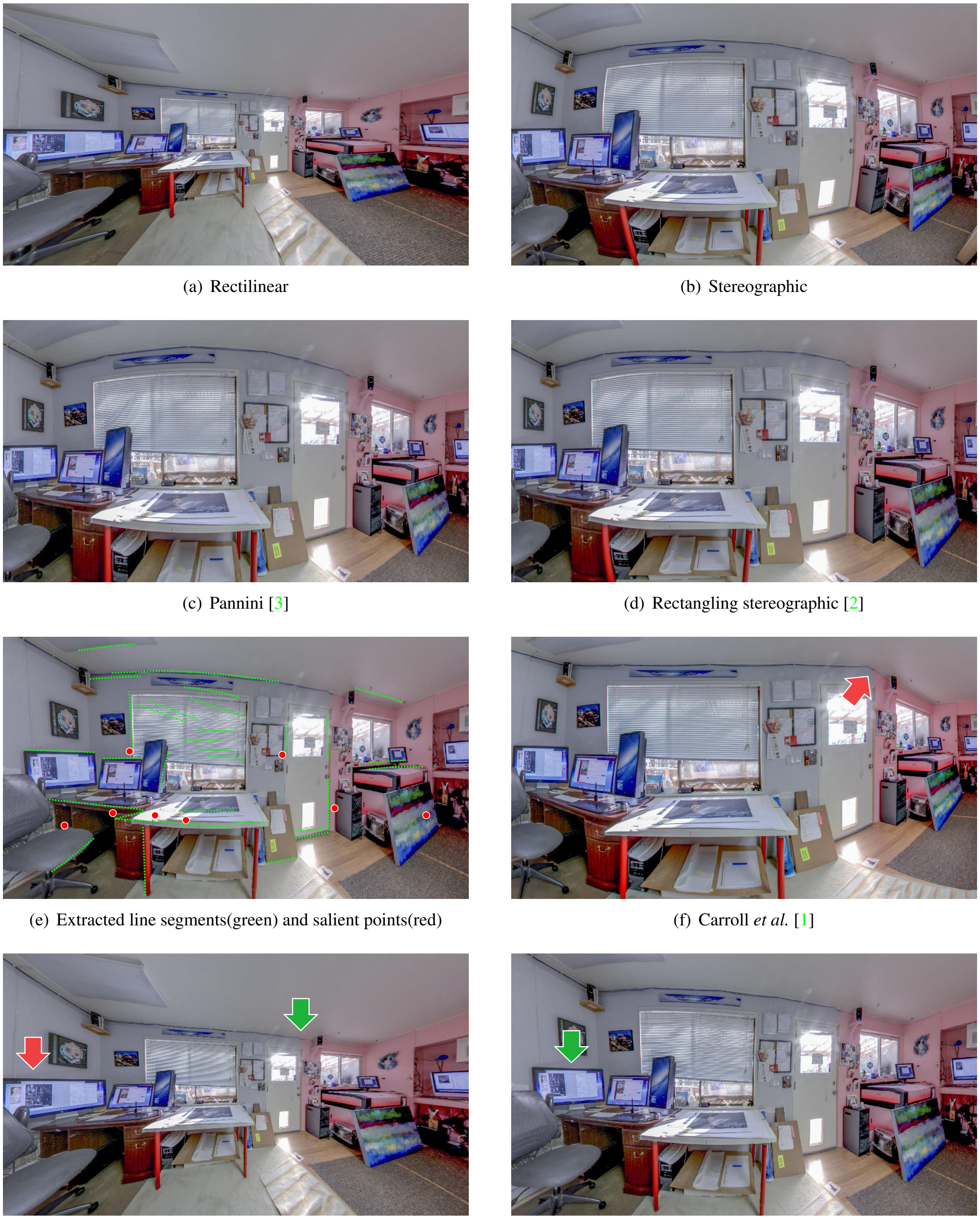
(f) Carroll *et al.* [1]



(g) Our result - optimized Pannini

(h) Our result - model interpolation

Figure 2. Carroll's method (f) distorts the bottom of the pool (red arrow) because the structure is not linear. Rectangling stereographic (d) bends the linear structures on diagonal regions (red arrow). Our algorithm (h) well preserves linear structures than other methods.



(a) Rectilinear

(b) Stereographic

(c) Pannini [3]

(d) Rectangling stereographic [2]

(e) Extracted line segments(green) and salient points(red)

(f) Carroll *et al.* [1]

(g) Our result - optimized Pannini

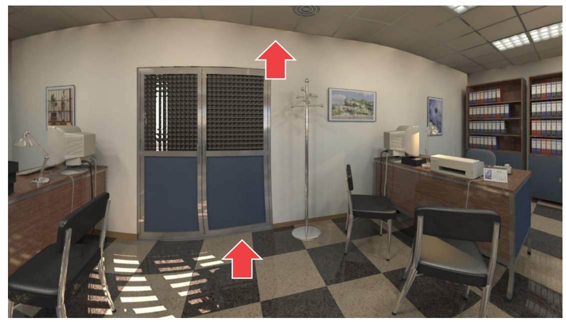
(h) Our result - model interpolation

Figure 3. Carroll's method (f) preserves a part of the linear structures but the line on the ceiling is bent (red arrow). Rectangling stereographic (d) also bends the line of the ceiling. Our optimization result (g) shows stretched objects at the boundary (red arrow). Model interpolation (h) generates slightly bent lines but the structure of the room is relatively well preserved (green arrow).

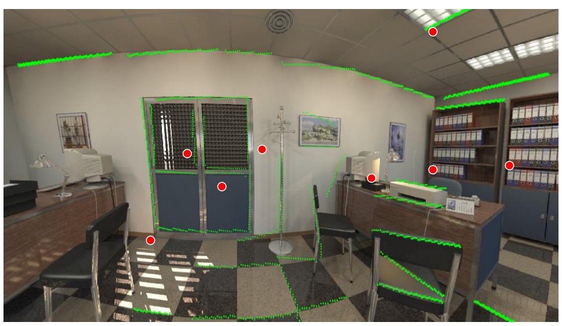
(a) Rectilinear

(b) Stereographic

(c) Pannini [3]

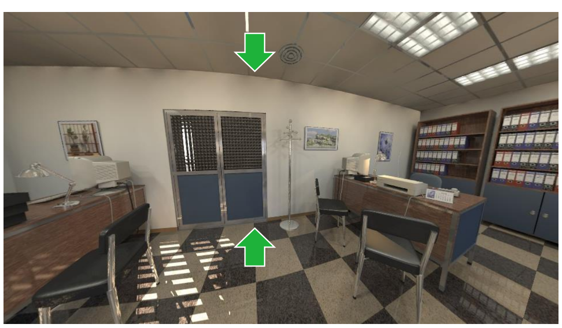


(d) Rectangling stereographic [2]



(e) Extracted line segments(green) and salient points(red)

(f) Carroll *et al.* [1]



(g) Our result - optimized Pannini

(h) Our result - model interpolation

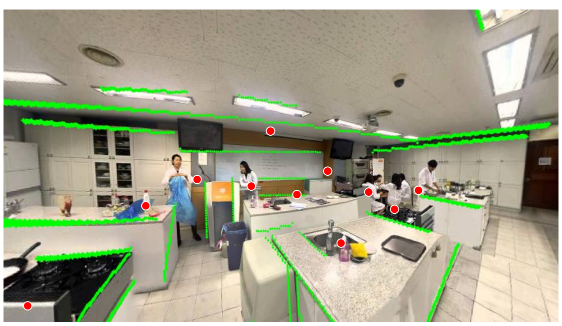
Figure 4. Rectangling stereographic (d) bends the linear structures on the wall (red arrows). Carroll's method (f) also bends the linear structures because the line segments are fragmented. On the other hand, our algorithms ((g) and (h)) relatively well preserve linear structures than other methods(green arrows).

(a) Rectilinear

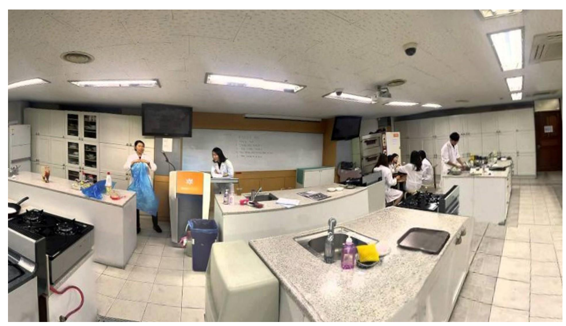
(b) Stereographic

(c) Pannini [3]

(d) Rectangling stereographic [2]



(e) Extracted line segments(green) and salient points(red)

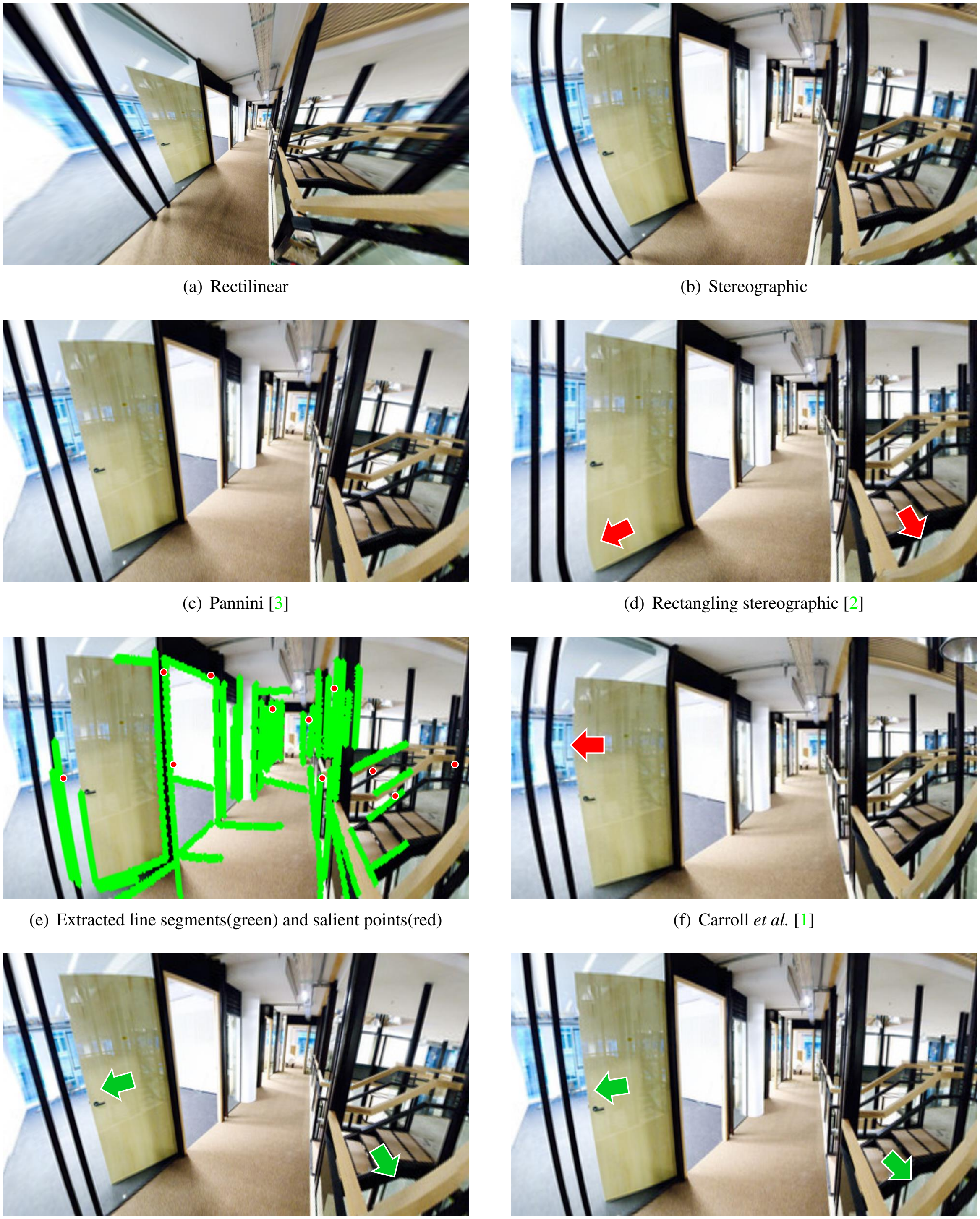


(f) Carroll *et al.* [1]

(g) Our result - optimized Pannini

(h) Our result - model interpolation

Figure 5. Carroll's method (f) cannot preserve the linear structures on the floor because they are occluded by objects. Rectangling stereographic (d) slightly bends the line of the ceiling (red arrow) than our algorithm (h) (green arrow).



(a) Rectilinear

(b) Stereographic

(c) Pannini [3]

(d) Rectangling stereographic [2]

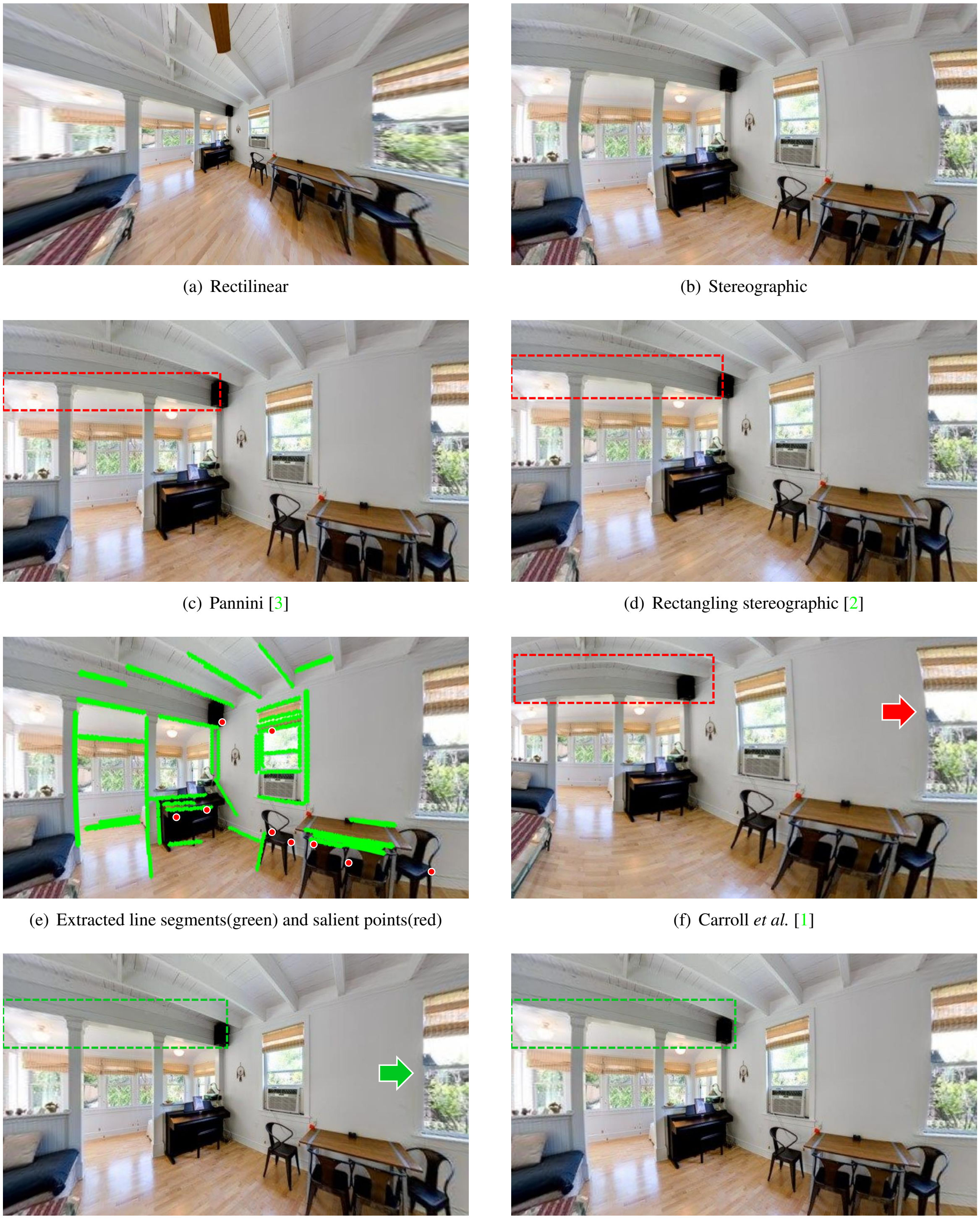
(e) Extracted line segments(green) and salient points(red)

(f) Carroll *et al.* [1]

(g) Our result - optimized Pannini

(h) Our result - model interpolation

Figure 6. Rectangling stereographic (d) highly distorts the line structure straddling the diagonal lines. Carroll's method (f) bends the line because the extracted lines are fragmented. On the other hand, our algorithms ((g) and (h)) relatively well preserve linear structures than other methods(green arrows).



(a) Rectilinear

(b) Stereographic

(c) Pannini [3]

(d) Rectangling stereographic [2]

(e) Extracted line segments(green) and salient points(red)

(f) Carroll *et al.* [1]

(g) Our result - optimized Pannini

(h) Our result - model interpolation

Figure 7. The linear structures on the ceiling in Pannini, Rectangling stereographic, and Carroll's method ((c), (d), and (f)) (red box) are slightly bent than our algorithms ((g) and (h)). Especially, Carroll's method highly distorts at the margin and the fragmented line structure.

References

[1] R. Carroll, M. Agrawala, and A. Agarwala. Optimizing content-preserving projections for wide-angle images. *ACM Transactions on Graphics-TOG*, 28(3):43, 2009. 1, 2, 3, 4, 5, 6, 7, 8

[2] C.-H. Chang, M.-C. Hu, W.-H. Cheng, and Y.-Y. Chuang. Rectangling stereographic projection for wide-angle image visualization. In *Proceedings of the IEEE International Conference on Computer Vision*, pages 2824–2831, 2013. 2, 3, 4, 5, 6, 7, 8

[3] T. K. Sharpless, B. Postle, and D. M. German. Pannini: a new projection for rendering wide angle perspective images. In *Proceedings of the Sixth international conference on Computational Aesthetics in Graphics, Visualization and Imaging*, pages 9–16. Eurographics Association, 2010. 1, 2, 3, 4, 5, 6, 7, 8