Time Interval Ray Tracing for Motion Blur Supplemental Materials

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Stratified Sampling, 1 spp

TIRT (Ours), 1 spp

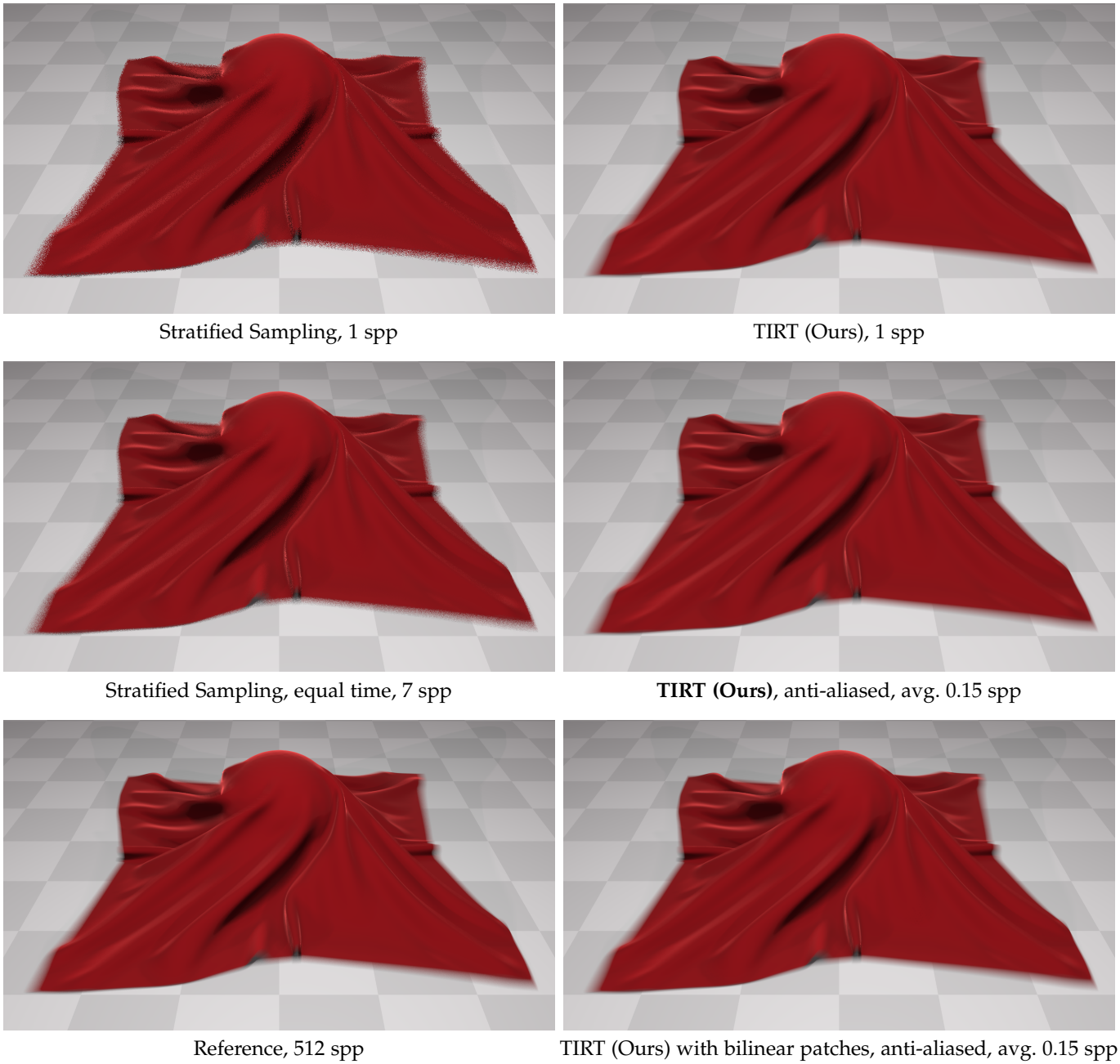
Stratified Sampling, equal time, 12 spp

TIRT (Ours), anti-aliased, avg. 0.48 spp

Reference, 1K spp

TIRT (Ours) with bilinear patches, anti-aliased, avg. 0.48 spp

Fig. 1. Full size comparison images of our time interval ray tracing method to stratified time sampling.

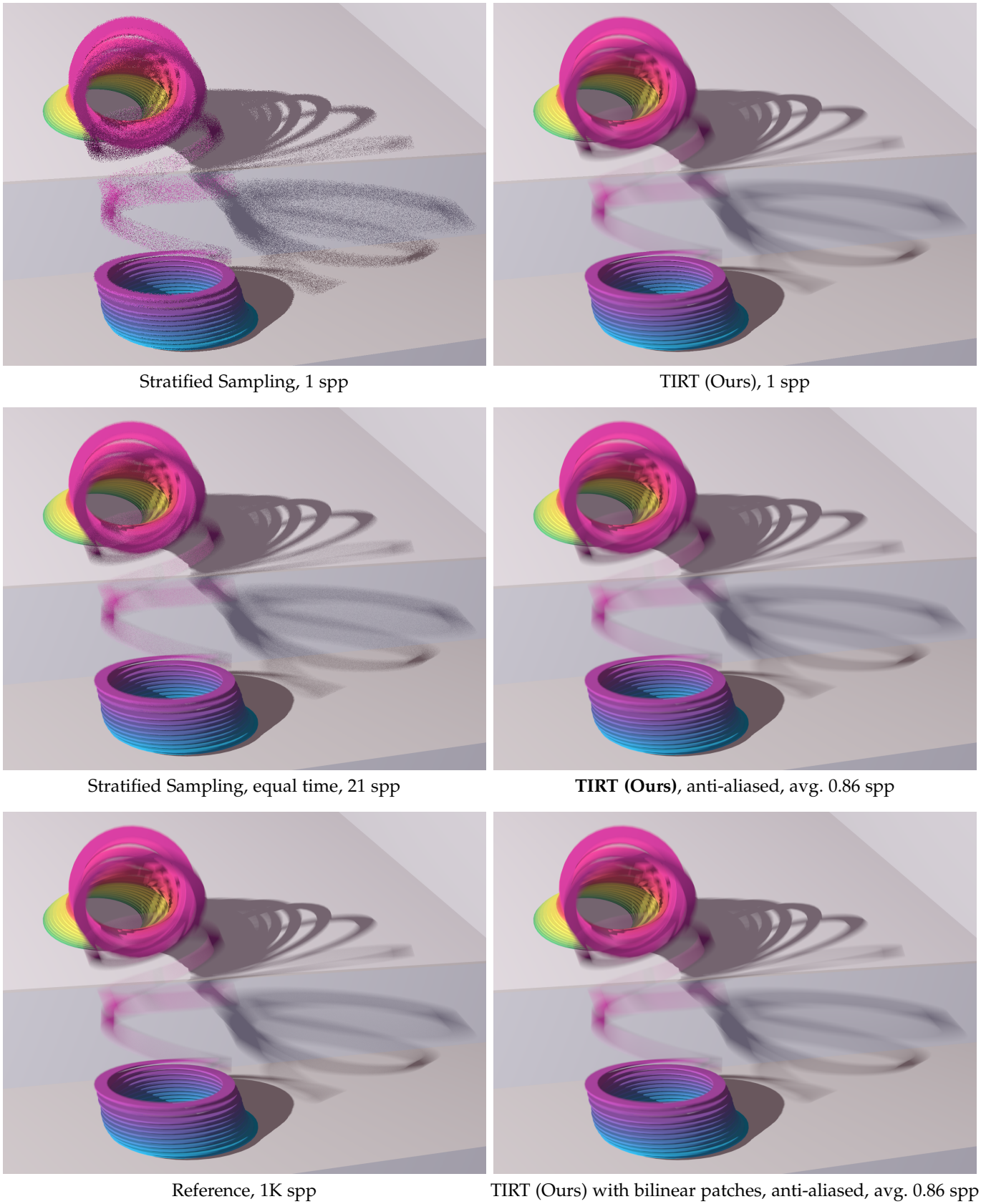


Stratified Sampling, 1 spp | TIRT (Ours), 1 spp

Stratified Sampling, equal time, 7 spp | **TIRT (Ours)**, anti-aliased, avg. 0.15 spp

Reference, 512 spp | TIRT (Ours) with bilinear patches, anti-aliased, avg. 0.15 spp

Fig. 2. Full size comparison images of our time interval ray tracing method to stratified time sampling.



Stratified Sampling, 1 spp

TIRT (Ours), 1 spp

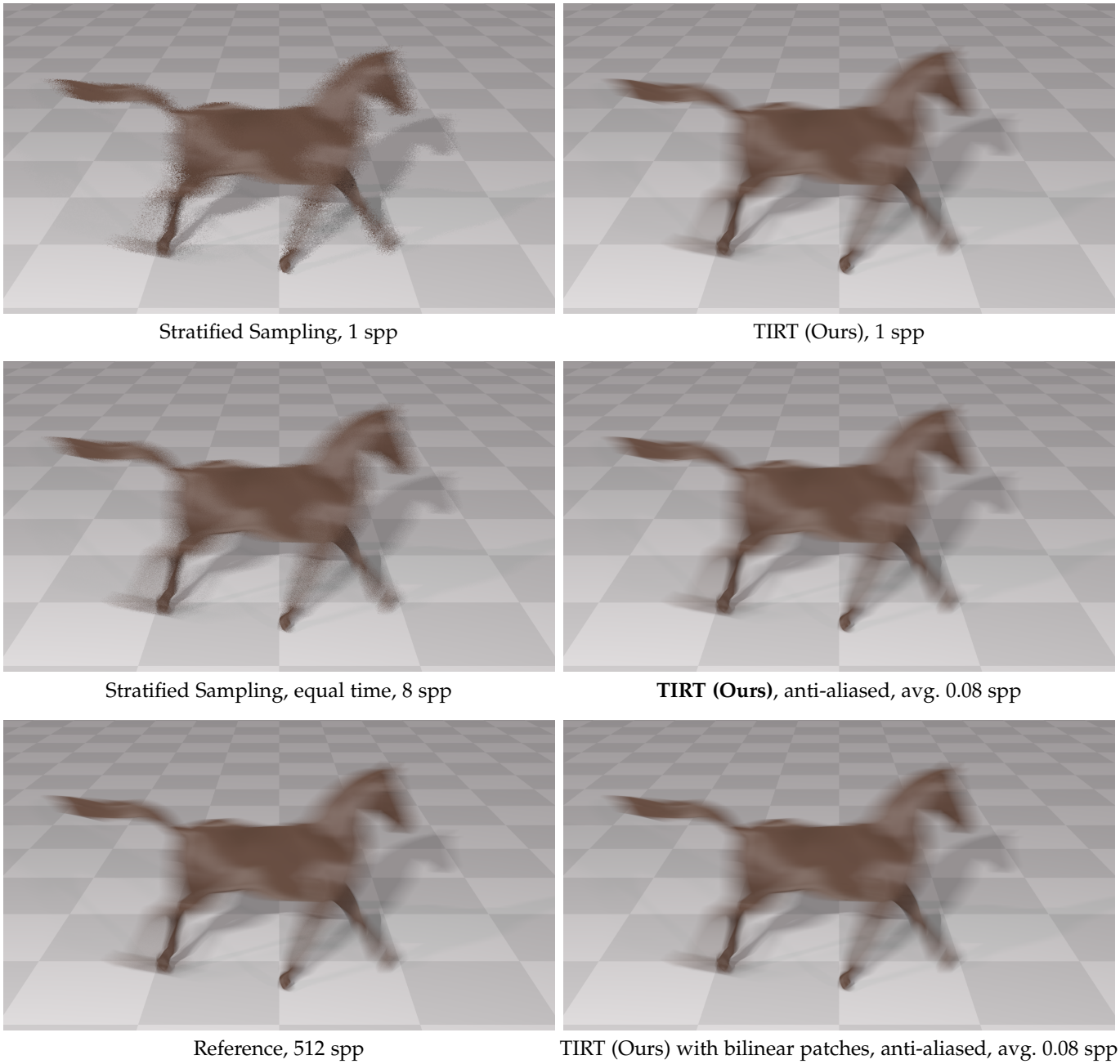
Stratified Sampling, equal time, 21 spp

TIRT (Ours), anti-aliased, avg. 0.86 spp

Reference, 1K spp

TIRT (Ours) with bilinear patches, anti-aliased, avg. 0.86 spp

Fig. 3. Full size comparison images of our time interval ray tracing method to stratified time sampling.



Stratified Sampling, 1 spp

TIRT (Ours), 1 spp

Stratified Sampling, equal time, 8 spp

TIRT (Ours), anti-aliased, avg. 0.08 spp

Reference, 512 spp

TIRT (Ours) with bilinear patches, anti-aliased, avg. 0.08 spp

Fig. 4. Full size comparison images of our time interval ray tracing method to stratified time sampling.

Stratified Sampling, 1 spp

TIRT (Ours), 1 spp

Stratified Sampling, equal time, 27 spp

TIRT (Ours), anti-aliased, avg. 1.14 spp

Reference, 512 spp

TIRT (Ours) with bilinear patches, anti-aliased, avg. 1.14 spp

Fig. 5. Full size comparison images of our time interval ray tracing method to stratified time sampling.

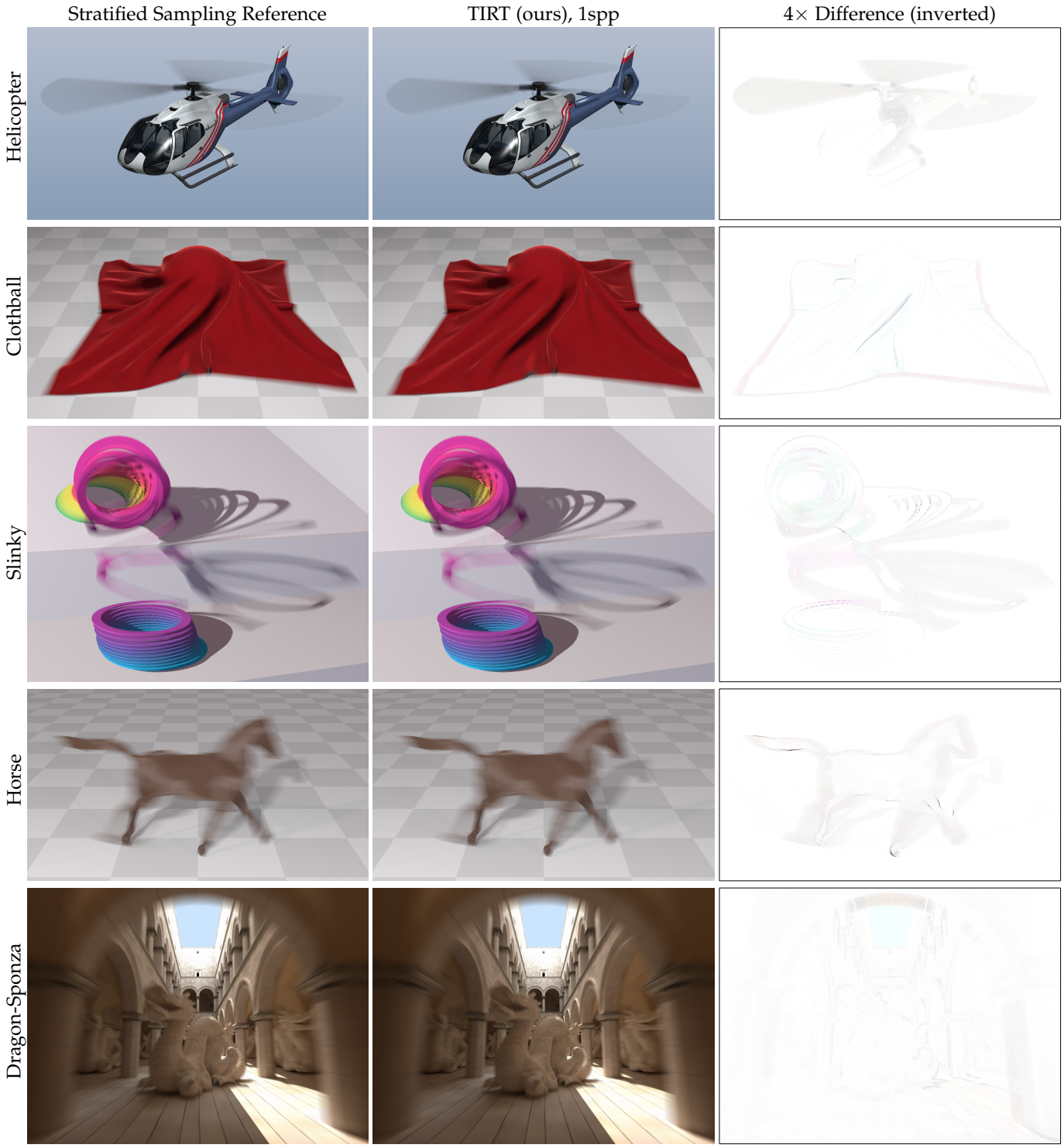


Fig. 6. Comparison images for motion blur sampled through pixel centers. Reference images are generated with stratified sampling in time using 1K samples per pixel, except for Slinky and Clothball which use 2K. Time Interval Ray Tracing (TIRT) images use only a single sample per pixel. The difference column compares the two images amplified by 4× (white means no difference). It is clear that time integration technique employed by TIRT resolves motion blur effectively.

Fig. 7. Comparison images for motion blur computed using Time Interval Ray Tracing (TIRT) with anti-aliasing (AA) while relying on triangles only (left) or bilinear patches (center). The difference column compares the two images amplified by 4× (white means no difference). The error metrics column computes the difference between the images using root mean square error (*RMSE*), peak signal to noise ratio (*PSNR*) and mean structural similarity (*MSSIM*). It is clear that triangles and bilinear patches produce highly similar images.

			Render Time	MRPS	Total Rays	Tri Tests / Ray	Patch Tests / Ray	Box Tests / Ray	Shading Calls
Helicopter	1 spp	triangles	4.98 sec	3.27	16.3M	3.0 + 11.6	0	22.5 + 24.9	3.4M
		patches	5.12 sec	3.31	17.0M	4.3 + 6.0	2.9	24.4 + 23.0	3.6M
	AA	triangles	14.25 sec	2.70	38.4M	2.7 + 14.5	0	20.5 + 35.7	8.2M
		patches	14.30 sec	2.79	39.9M	3.6 + 7.9	3.4	22.2 + 33.1	8.6M
Clothball	1 spp	triangles	14.1 sec	3.59	50.7M	2.0 + 3.5	0	38.6 + 12.0	17.3M
		patches	15.9 sec	3.19	50.6M	4.6 + 1.3	1.6	49.7 + 11.8	17.2M
	AA	triangles	8.13 sec	3.20	26M	1.9 + 4.9	0	37.1 + 15.5	9.4M
		patches	8.98 sec	2.89	26M	4.5 + 1.9	2.3	48.4 + 15.2	9.4M
Slinky	1 spp	triangles	3.10 sec	1.97	6.1M	5.6 + 18.8	0	28.2 + 28.4	4.5M
		patches	2.85 sec	2.14	6.1M	5.6 + 4.5	9.1	28.1 + 24.0	4.5M
	AA	triangles	9.14 sec	2.08	19.1M	8.2 + 13.2	0	43.2 + 21.1	16.2M
		patches	8.62 sec	2.19	18.9M	8.2 + 3.8	6.0	43.2 + 18.2	16.0M
Horse	1 spp	triangles	7.35 sec	2.65	19.5M	2.3 + 15.0	0	21.7 + 18.3	5.8M
		patches	6.99 sec	2.84	19.8M	3.5 + 0.9	8.5	24.9 + 14.8	5.9M
	AA	triangles	4.17 sec	2.64	11.0M	2.7 + 14.4	0	25.6 + 15.7	3.4M
		patches	3.90 sec	2.79	10.9M	4.0 + 0.8	8.2	29.1 + 12.6	3.4M
Dragon-Sponza	1 spp	triangles	9.05 sec	0.172	1.6M	0 + 108.6	0	0 + 284.1	44.8M
		patches	9.04 sec	0.172	1.6M	0 + 44.4	61.7	0 + 321.5	44.8M
	AA	triangles	13.64 sec	0.177	2.4M	0 + 108.1	0	0 + 296.8	77.9M
		patches	13.42 sec	0.180	2.4M	0 + 42.2	56.8	0 + 317.9	77.9M

Fig. 8. Render statistics for motion blur computed using Time Interval Ray Tracing (TIRT) with 1 sample per pixel (*1 spp*) or anti-aliasing (*AA*) while relying on either *triangles* or bilinear *patches*. The number of intersection tests *Tri Tests/Ray* and *Box Tests/Ray* are provided as the sum of the values for *time sample rays* and *interval rays*. The number of bilinear patch intersection tests is provided in *Patch Tests/Ray* column. *MRPS* stands for millions of rays per second.

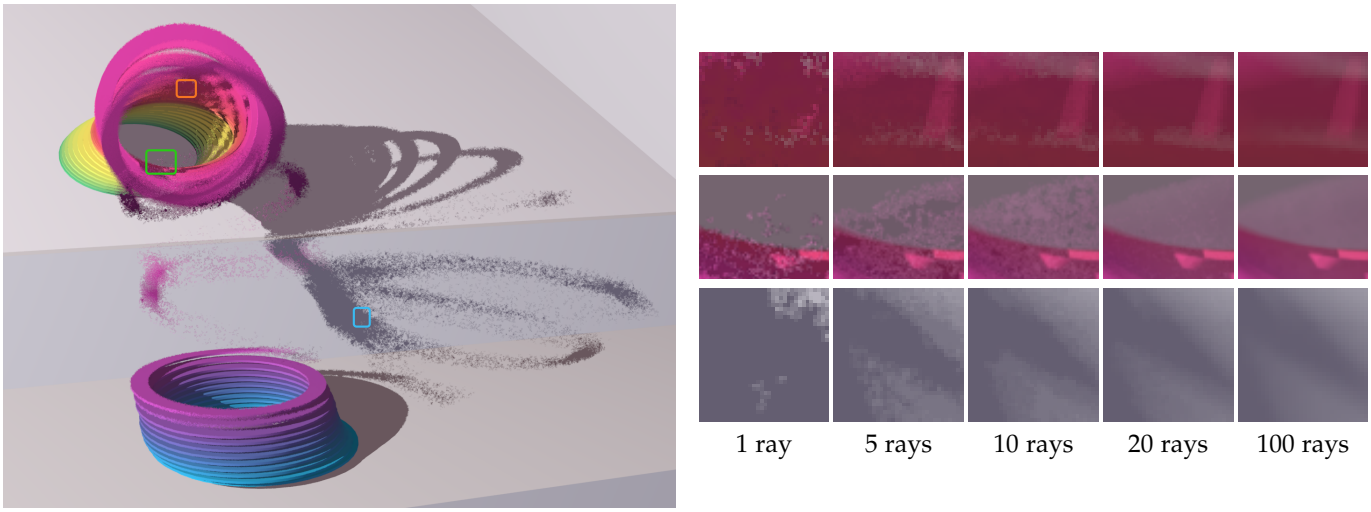
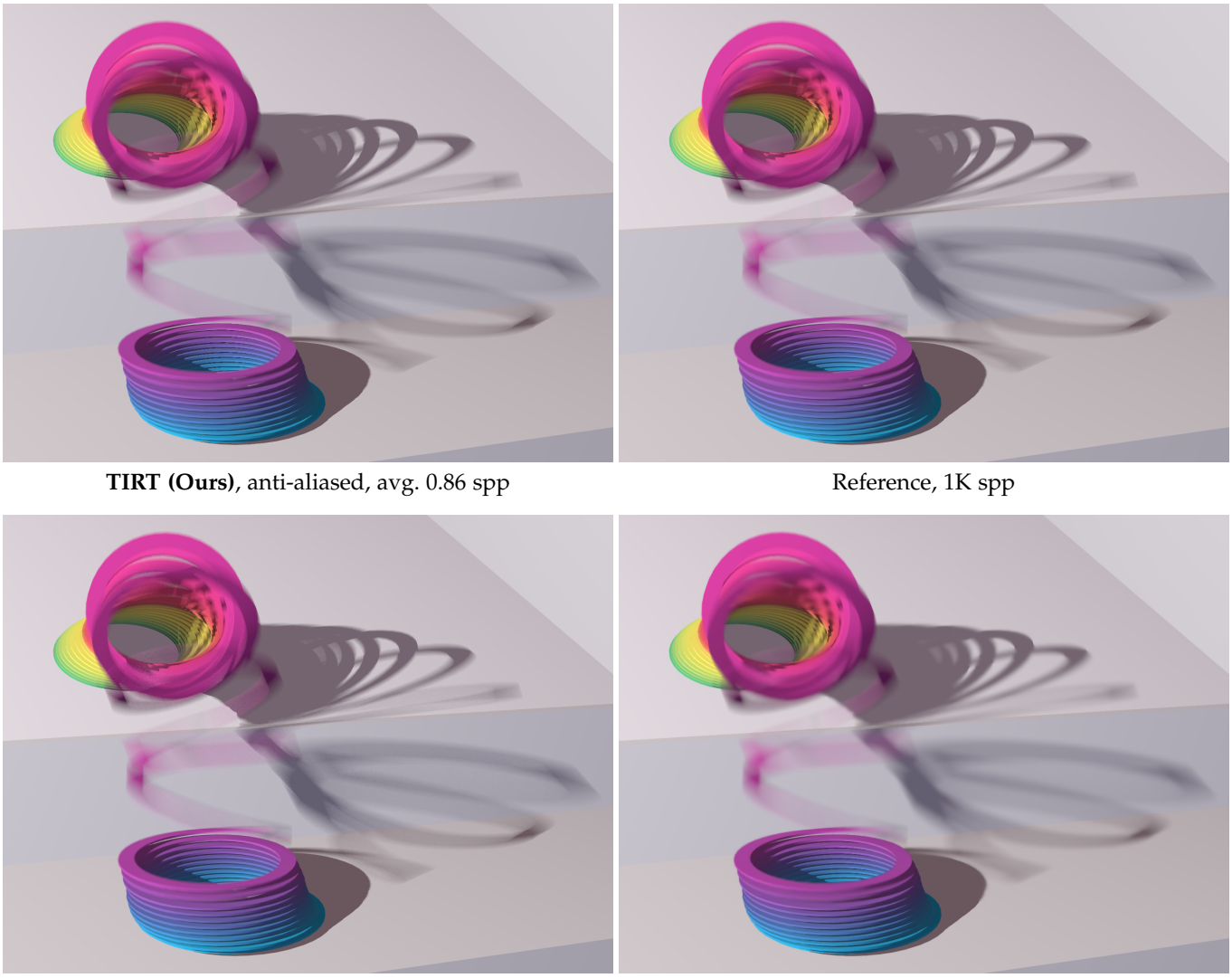


Fig. 9. Anti-aliasing using adaptive subdivision is not suitable for time sampling. The left image uses one ray with a time sample for each image-space sample. The enlarged portions to the right show the improvement of using more rays with distinct time samples while sharing the same image-space sample. Unless enough time samples are used to completely resolve the motion, adaptive subdivision anti-aliasing produces severe visual artifacts.



TIRT (Ours), anti-aliased, avg. 0.86 spp

Reference, 1K spp

Stratified Sampling, 20 spp

RPF, using Stratified Sampling, 20 spp

Fig. 10. Comparison images for motion blur using the Slinky scene. RPF image in bottom right relies on Random Parameter Filtering (RPF) applied to the samples generated by Stratified Sampling at 20 spp. Although the image is mostly smooth, there are noticeable differences with the Reference in the areas of heavy and overlapping motion blur.