Supplement to Progressive Shell Quasistatics for Unstructured Meshes

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CCS Concepts: • **Computing methodologies** → **Physical simulation**.

Additional Key Words and Phrases: Progressive Simulation, Multiresolution, Model Reduction, Shell Simulation, Contact Mechanics

ACM Reference Format:
Jiayi Eris Zhang, Jèrèmie Dumas, Yun (Raymond) Fei, Alec Jacobson, Doug L. James, and Danny M. Kaufman. 2023. Supplement to Progressive Shell Quasistatics for Unstructured Meshes. *ACM Trans. Graph.* 42, 6, Article 184 (December 2023), 2 pages. https://doi.org/10.1145/3618388

1 STRUCTURED MESH COMPARISON WITH PCS [ZHANG ET AL. 2022]

To complement our unstructured mesh comparison with prior work PCS (see Figure 12 and §5.1 of our main document), we provide an additional comparison with a PCS simulation using a fully *structured* mesh hierarchy for the can crush test. Here, rather than a high-quality unstructured base mesh, we introduce a structured mesh for PCS's coarsest level-0 and then build its hierarchy via its Loop subdivision to match the number of DOFs and triangle counts at each successive level with a comparable PSQ hierarchy. We can then use the same *structured* mesh at the finest level for the PSQ and PCS simulations. Here in Figure 1 (top row), we see that similarly with structured meshes PCS again consistently suffers from severe artificial locking, resulting in poor-quality coarse preview simulations across hierarchy levels, while even the resolution at the finest level is insufficient to capture reasonable modeling of the buckling. In contrast (Figure 1 bottom row), PSQ again captures consistent high-quality buckling across resolutions in its hierarchy.

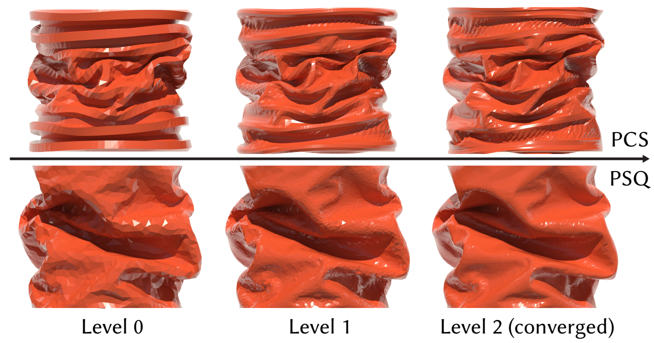

Fig. 1. **Can Crush Comparison on Structured Mesh Hierarchies:** We compare prior work PCS [Zhang et al. 2022] and our PSQ method on a can crush test where both utilize the same structured, finest-level mesh (in contrast to the unstructured mesh test in Figure 12 of the main document). (Top row) While utilizing a structured mesh for PCS's initial coarse level-0 subsequently ensures high-quality finer-level meshes throughout, PCS continues to generate shell simulation artifacts across all levels.

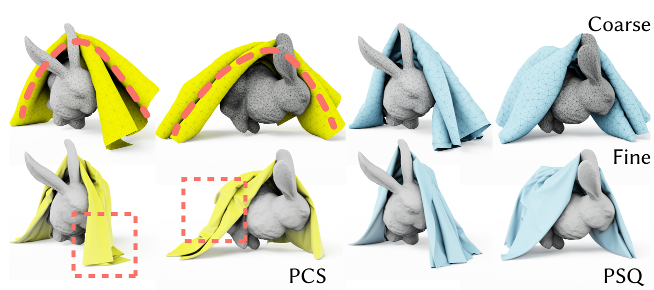

Fig. 2. **Sleepy Bunny:** In a simple cloth draping test, PCS's prolongation significantly over-estimates the overall material stiffness of the bunny's blanket, resulting in a silhouette that insufficiently "droops" in preview. In contrast, PSQ much better captures the material's bulk stiffness.

2 EXAMPLE STATISTICS

In Table 1, we list parameters and model statistics for the PCS examples in our paper. We list resolutions of the coarsest ($\#V_c$) and finest ($\#V_f$) models, the number of refinement levels (#levels), whether and how much strain limiting is in effect (SL), the friction coefficient (μ), the material thickness (d), density (ρ), membrane stiffness (E_{mem}), bending stiffness E_{bend}, and Poisson's ratio (ν).

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0730-0301/2023/12-ART184 $15.00
https://doi.org/10.1145/3618388

REFERENCES

Jiayi Eris Zhang, Jérémie Dumas, Yun (Raymond) Fei, Alec Jacobson, Doug L. James, and Danny M. Kaufman. 2022. Progressive Simulation for Cloth Quasistatics. *ACM Trans. Graph.* 41, 6, Article 218 (nov 2022), 16 pages. https://doi.org/10.1145/3550454.3555510

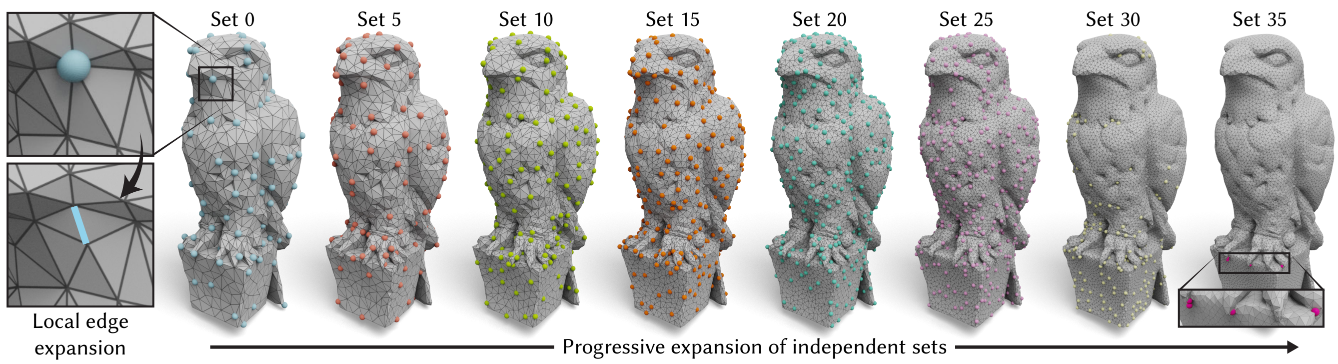

Fig. 3. **Visualization of independent sets:** we achieve the expansion from $\mathcal{M}_l$ to $\mathcal{M}_{l+1}$ by parallelizing it into batches via coloring. To precompute our graph coloring, we trace the dependency graph derived from the initial forward decimation and apply greedy coloring to vertices (linked to edges for expansion) with combinatorial independence. Subsequently, we dynamically expand and update the mesh, based on which we repeat the same process until we achieve the full high-resolution shape reconstruction. Dots with the same color are identified as viable candidates for simultaneous expansion into new edges with newly inserted vertices (see the zoomed-in view).

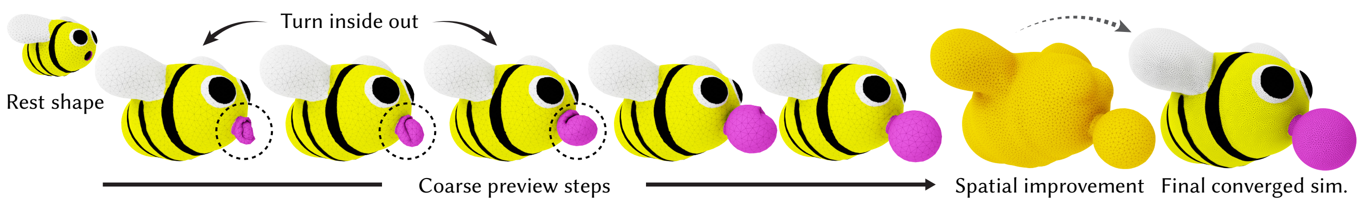

Fig. 4. **Bubbling Balloon:** A "bubble bee" balloon toy blows a bubble, demonstrating a challenging case of turning an internal part of the bee outward for which PSQ produces consistent results for both the coarse and fine level simulations.

Table 1. Model statistics.

Model	$\#V_c$	$\#V_f$	#levels	SL	μ	d	ρ	E_{mem}	E_{bend}	ν
Fig. 1 Green, yellow and purple characters	2.2K	100K	4	1.3	0.3	5.00E-05	46000	1.00E+05	1.00E+05	0.45
Fig. 1 Orange and red characters	2.0K	60K	4	1.3	0.3	5.00E-05	920	1.00E+05	1.00E+05	0.45
Fig. 1 Rigid colliders	9.8K	81K	4	n/a	0.3	0	0	0	0	0
Fig. 2 Pumpkin	3.6K	57K	3	n/a	0.3	1.00E-04	2710	7.00E+10	7.00E+10	0.33
Fig. 3 (and Fig. 12) Mat	5.8K	90K	3	3.0	0.3	3.00E-04	472.6	8.21E+05	8.21E+05	0.243
Fig. 4 (and Fig. 11) Soda can	2.9K	45K	3	n/a	0.1	1.00E-05	2710	7.00E+10	7.00E+10	0.33
Fig. 13 Cloth on sphere	0.2K	10K	4	1.06	0.1	3.18E-04	472.6	8.21E+03	8.21E+04	0.243
Fig. 14 Hat on sphere	0.8K	12K	3	1.06	0.1	3.18E-04	472.6	8.21E+05	8.21E+05	0.243
Fig. 15 Spot	1.6K	25K	3	1.06	0.1	3.18E-04	413.3	8.21E+05	8.21E+05	0.243
Fig. 16 Plate	1.6K	24K	3	n/a	0.1	3.18E-04	472.6	7.00E+10	7.00E+10	0.33
Fig. 17 Half dome	0.8K	14K	3	n/a	0.1	1.00E-03	1060	3.00E+08	3.00E+08	0.4
Fig. 18 Monster	5.0K	80K	3	1.2	0.3	5.00E-05	920	1.0E+05	1.0E+05	0.45
Fig. 19 Goyle	1.0K	80K	5	1.2	0.3	1.00E-06	920	1.0E+05	1.0E+05	0.45
Fig. 1 in supplemental Soda can	2.9K	45K	3	n/a	0.1	1.00E-05	2710	7.00E+10	7.00E+10	0.33
Fig. 2 in supplemental Cloth on bunny	1.6K	100K	4	1.06	0.3	3.18E-04	472.6	8.21E+04	8.21E+04	0.243
Fig. 4 in supplemental Bee	3.2K	50K	3	1.8	0.2	5.00E-05	920	1.00E+05	1.00E+05	0.45