

Deep Reconstruction of 3D Smoke Densities from Artist Sketches



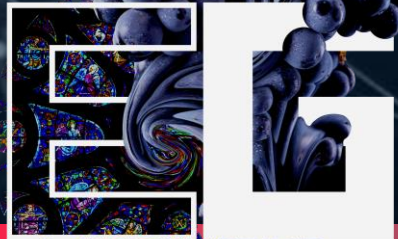
Byungsoo Kim¹ Xingchang Huang^{1,2} Laura Wuelfroth¹ Jingwei Tang¹

Guillaume Cordonnier^{1,3} Markus Gross¹ Barbara Solenthaler¹

¹ **ETH** zürich

²  **mpii** max planck institut
informatik

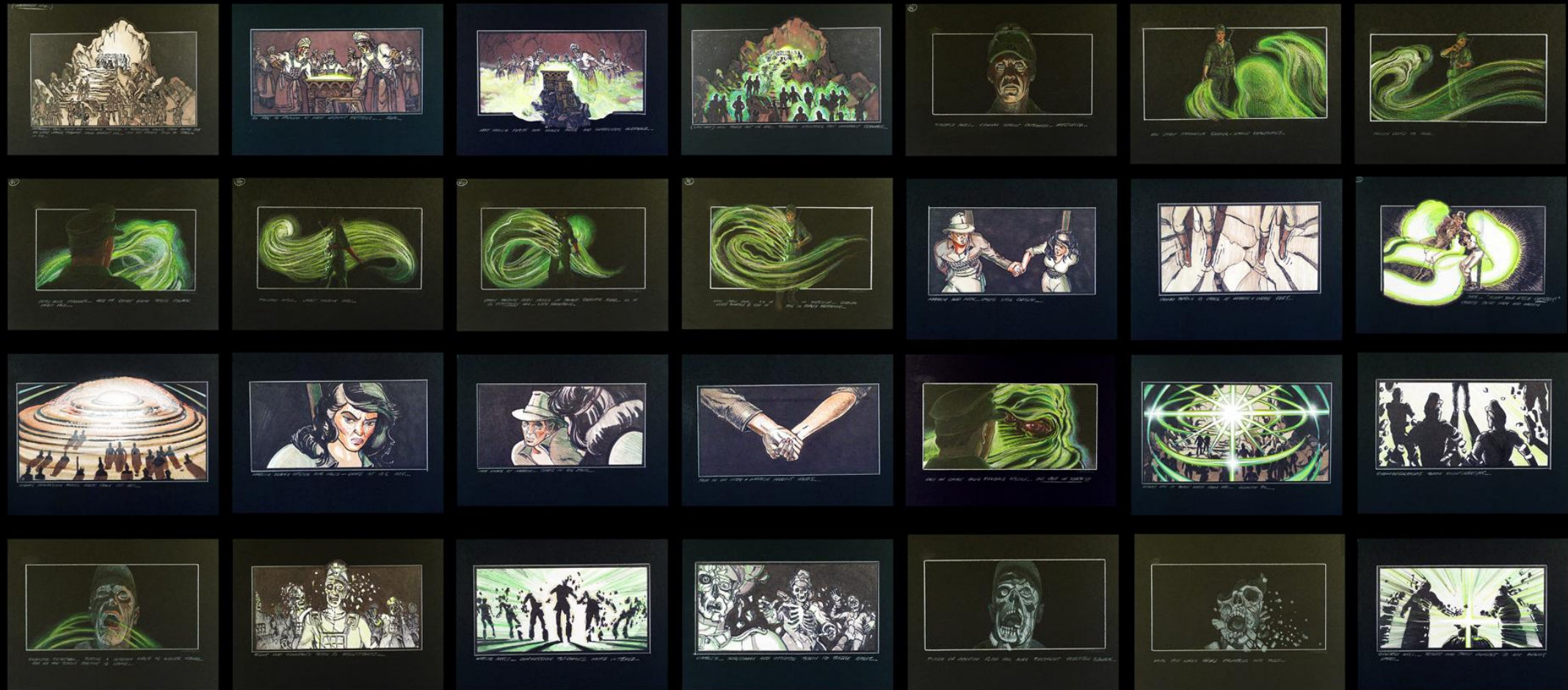
³ *Inria*



Reims 2022

Storyboard to Film

Raiders of the Lost Ark (1981) by Steven Spielberg



Storyboard to Film

Raiders of the Lost Ark (1981) by Steven Spielberg



TRUSS CLOSE TO HIM...



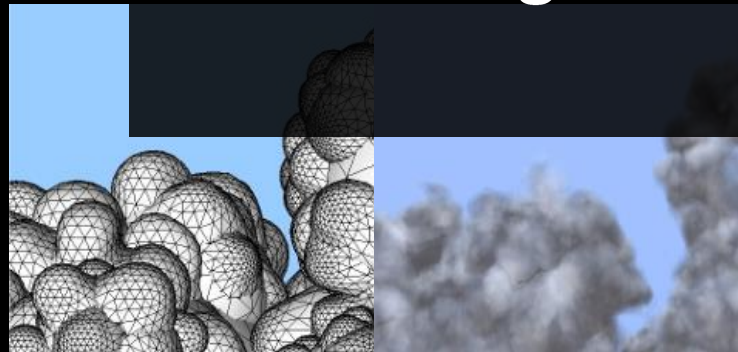
Storyboards by Ed Verreux, [Video](#) comparison by Vashi Nedomansky

Modeling Density Volumes

Detail Synthesis on Coarse Shapes



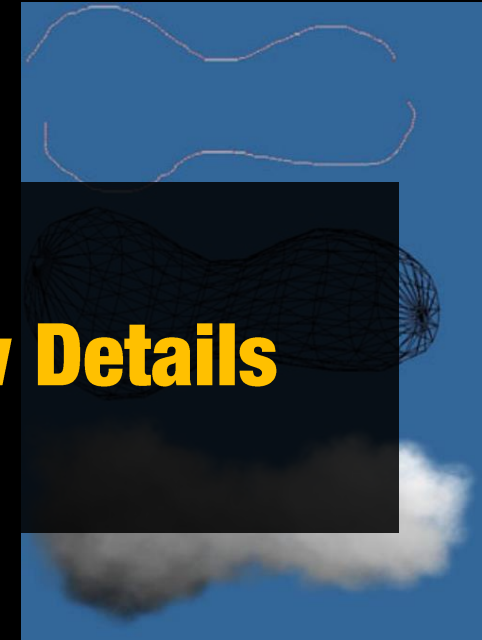
Procedural [Cohen et al. 1985]



Hierarchical Blobs [Bouthors and Neyret 2004]



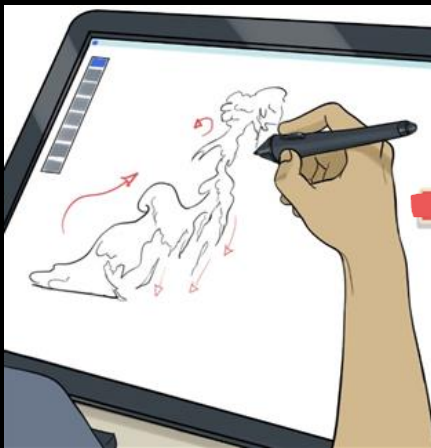
Skeleton / Rendering [Wither et al. 2008]



Noise [Stiver et al. 2010]

Challenge : Capturing Intrinsic Flow Details

Deep Reconstruction of 3D Smoke Densities from Artist Sketches



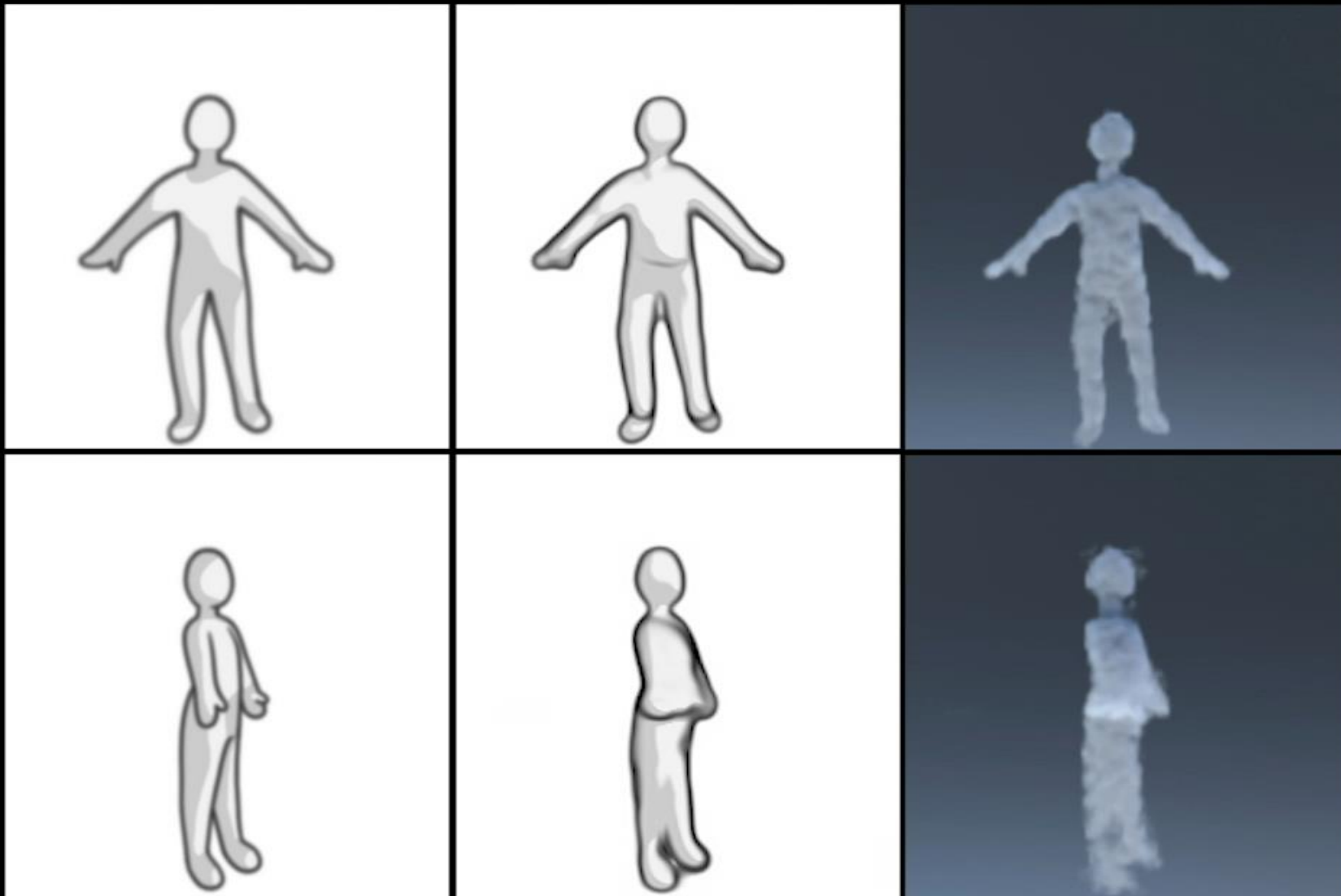
Artist Sketch

**Cross-Domain
Generative
Model**



Fluid Model

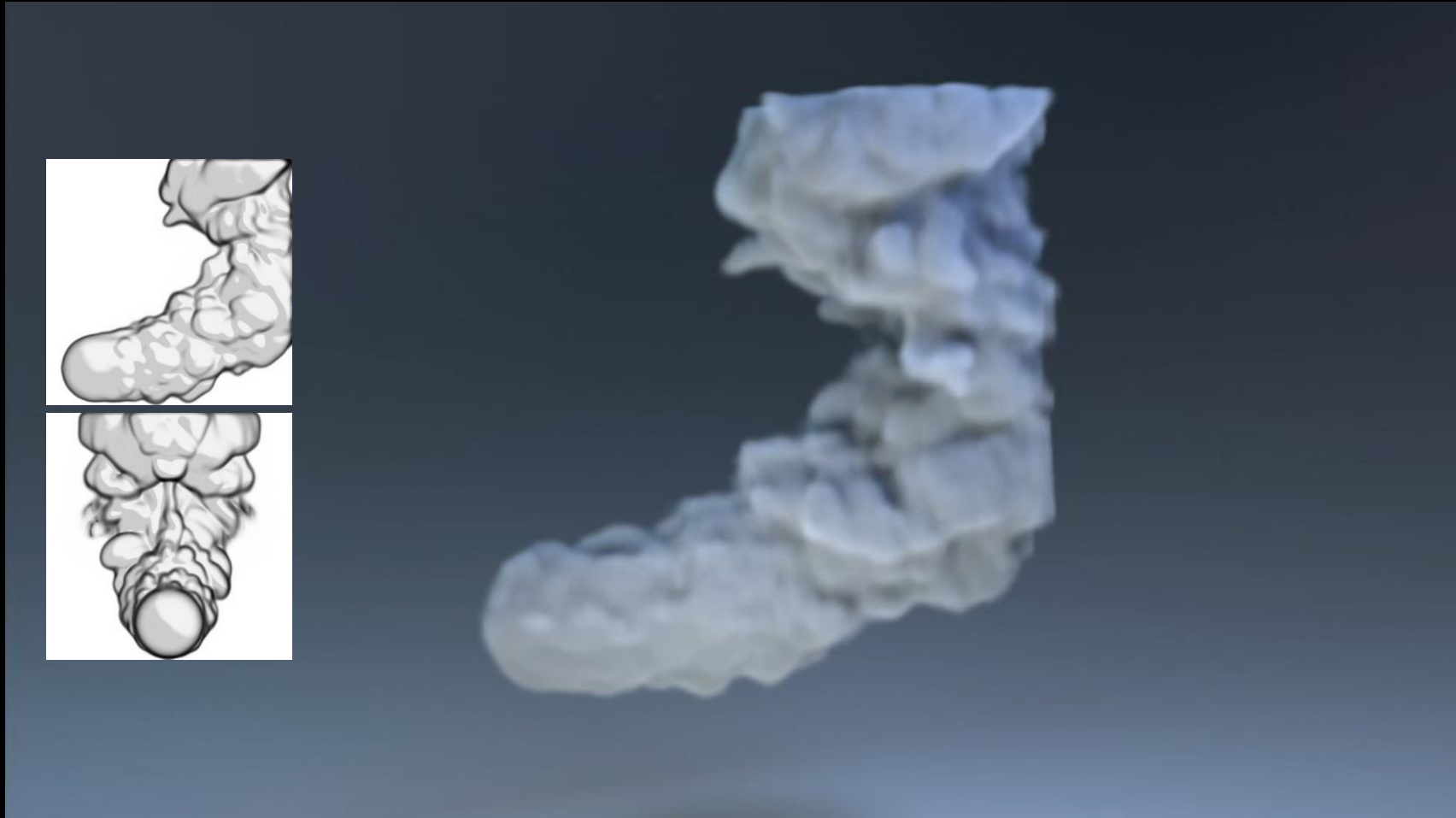
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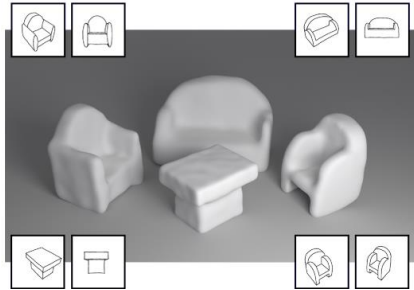
Artist Input

Ours

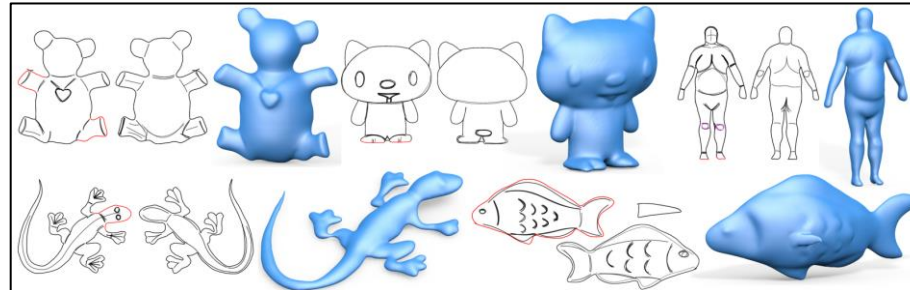
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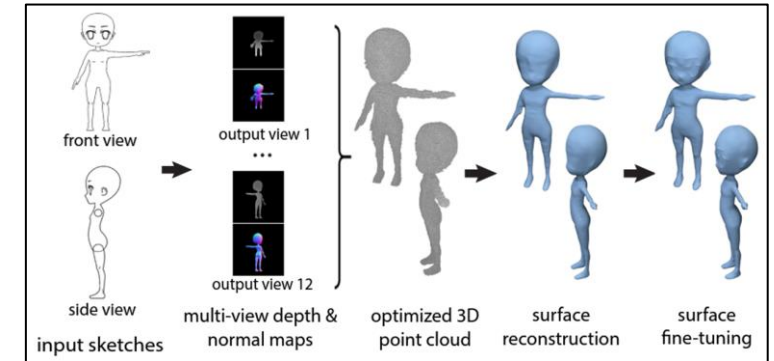
Prior Works: Learning-based Sketch Modeling



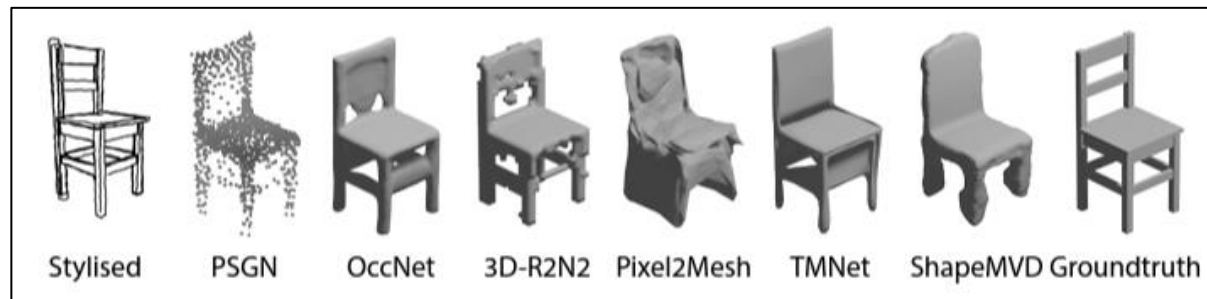
[Delanoy et al. 2018]



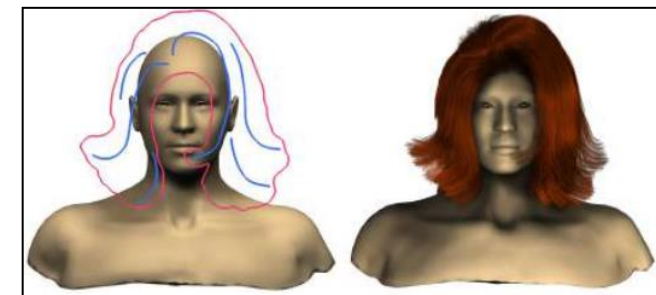
[Li et al. 2018]



[Lun et al. 2017]

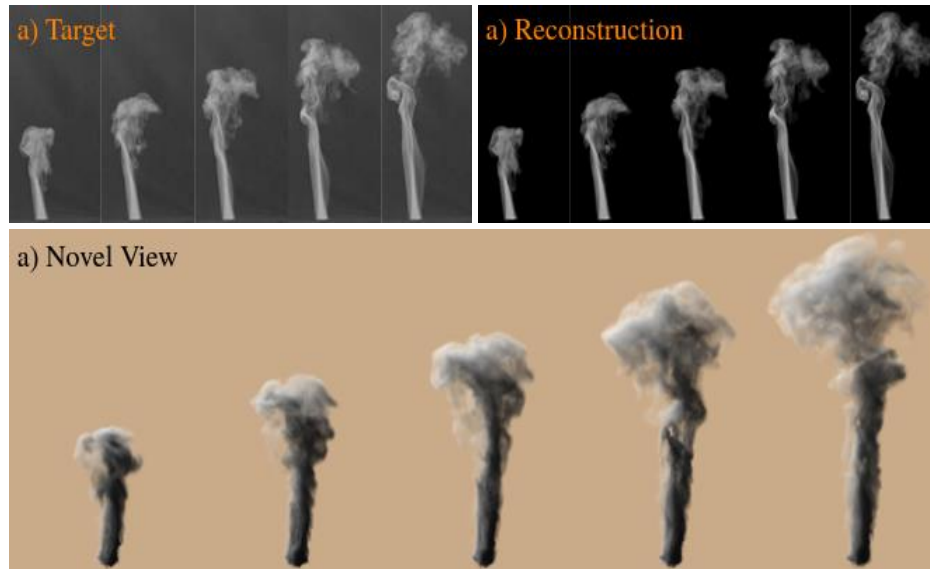


[Zhong et al. 2020]

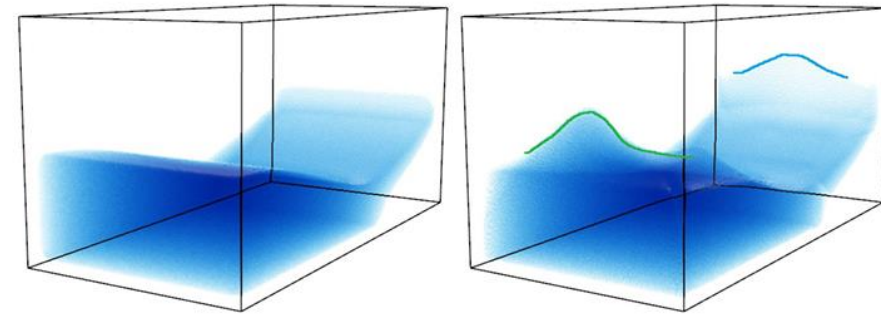


[Shen et al. 2020]

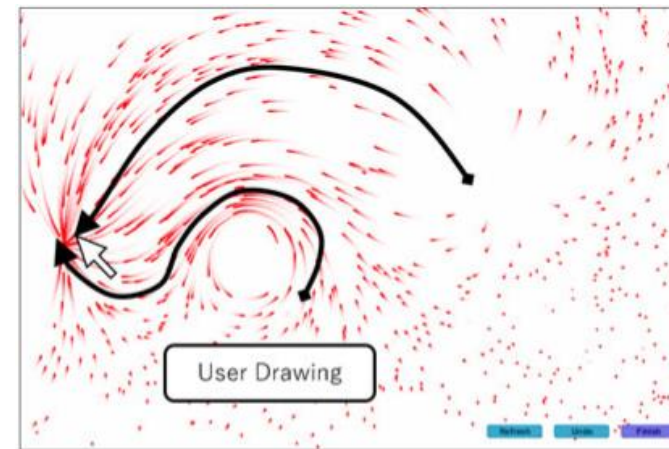
Prior Works: Fluid Reconstruction / Sketch Editing



[Franz et al. 2021]

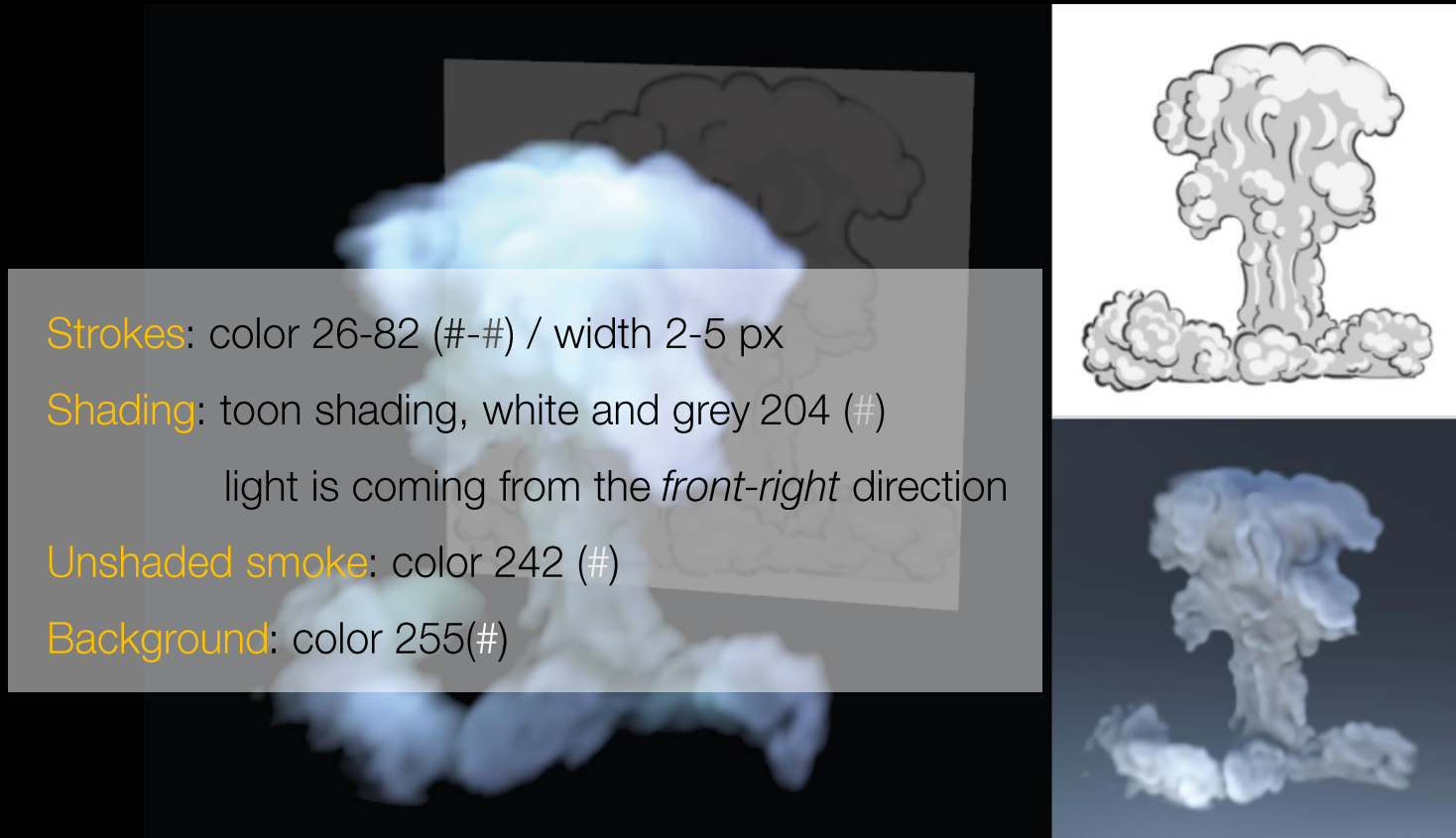


[Pan et al. 2013]



[Hu et al. 2019]

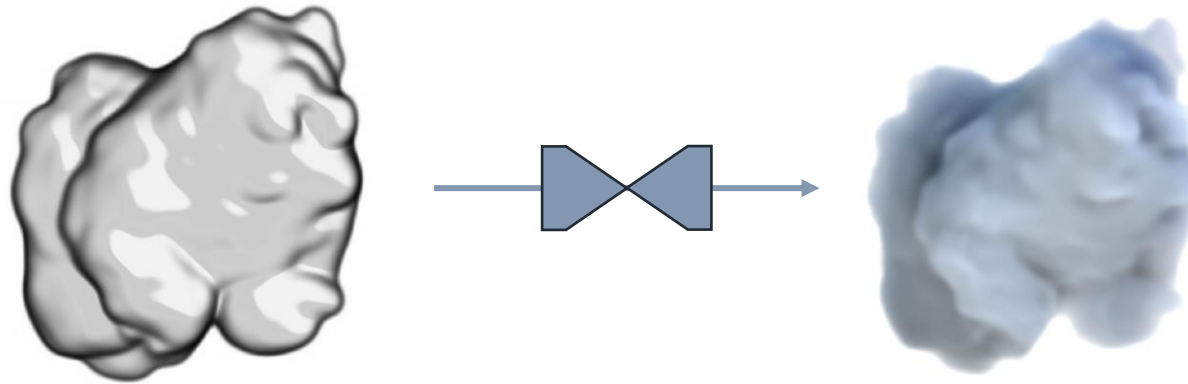
How to Sketch Fluids?



✓ **Generality** – ✓ **Simplicity** – ✓ **Strokes** – ✓ **Volume**

Pipeline: Progressive Refinement

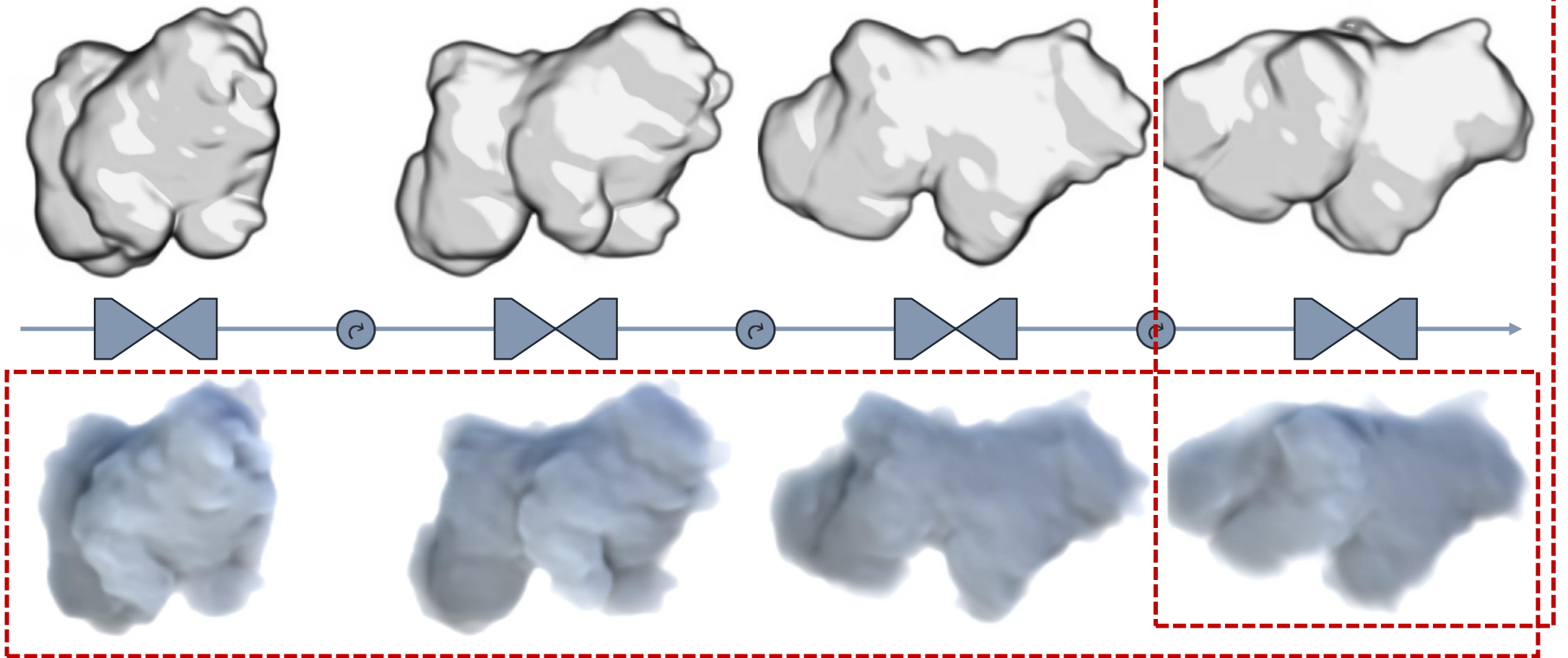
- 2D Sketch-based Modeling



Depth Ambiguity & Occlusions

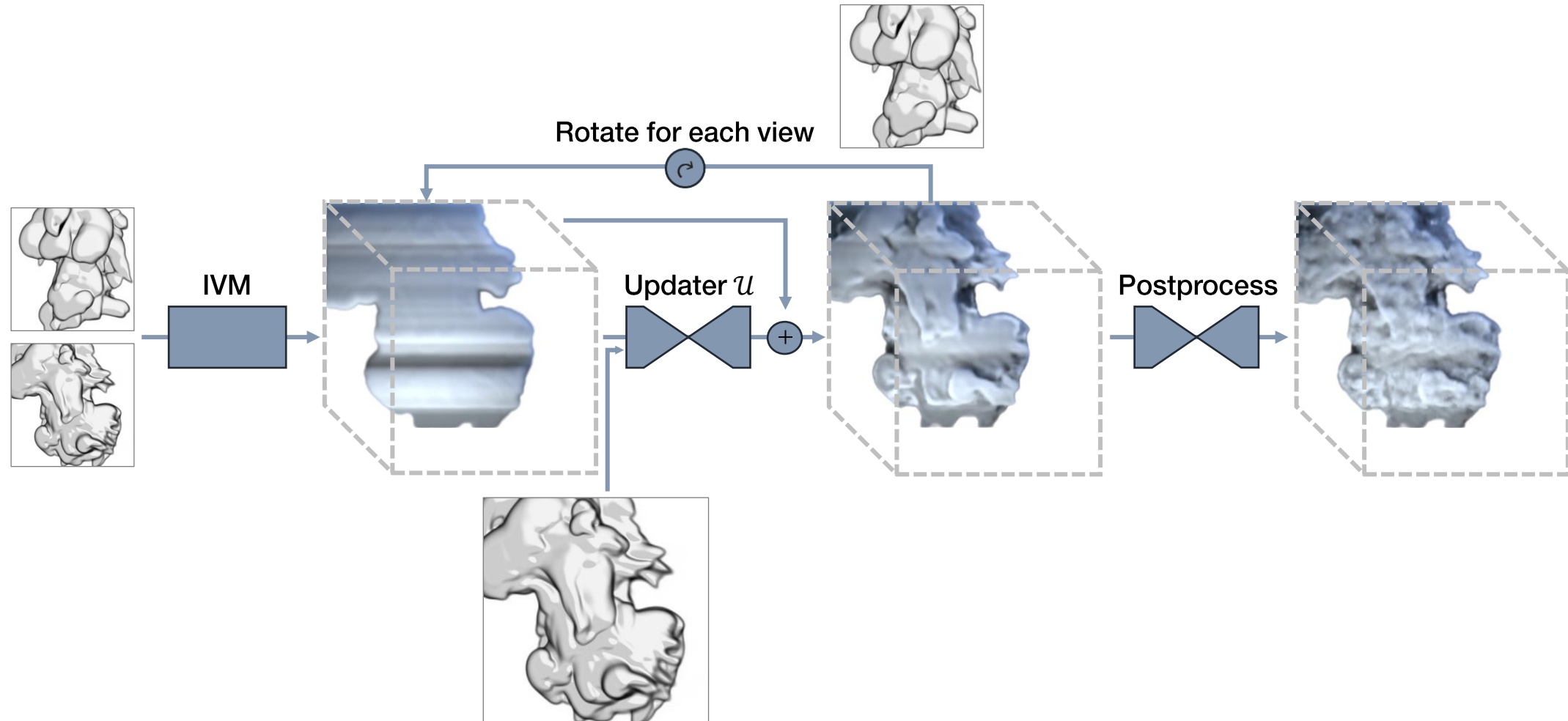
Pipeline: Progressive Refinement

1. Accurate Correspondence

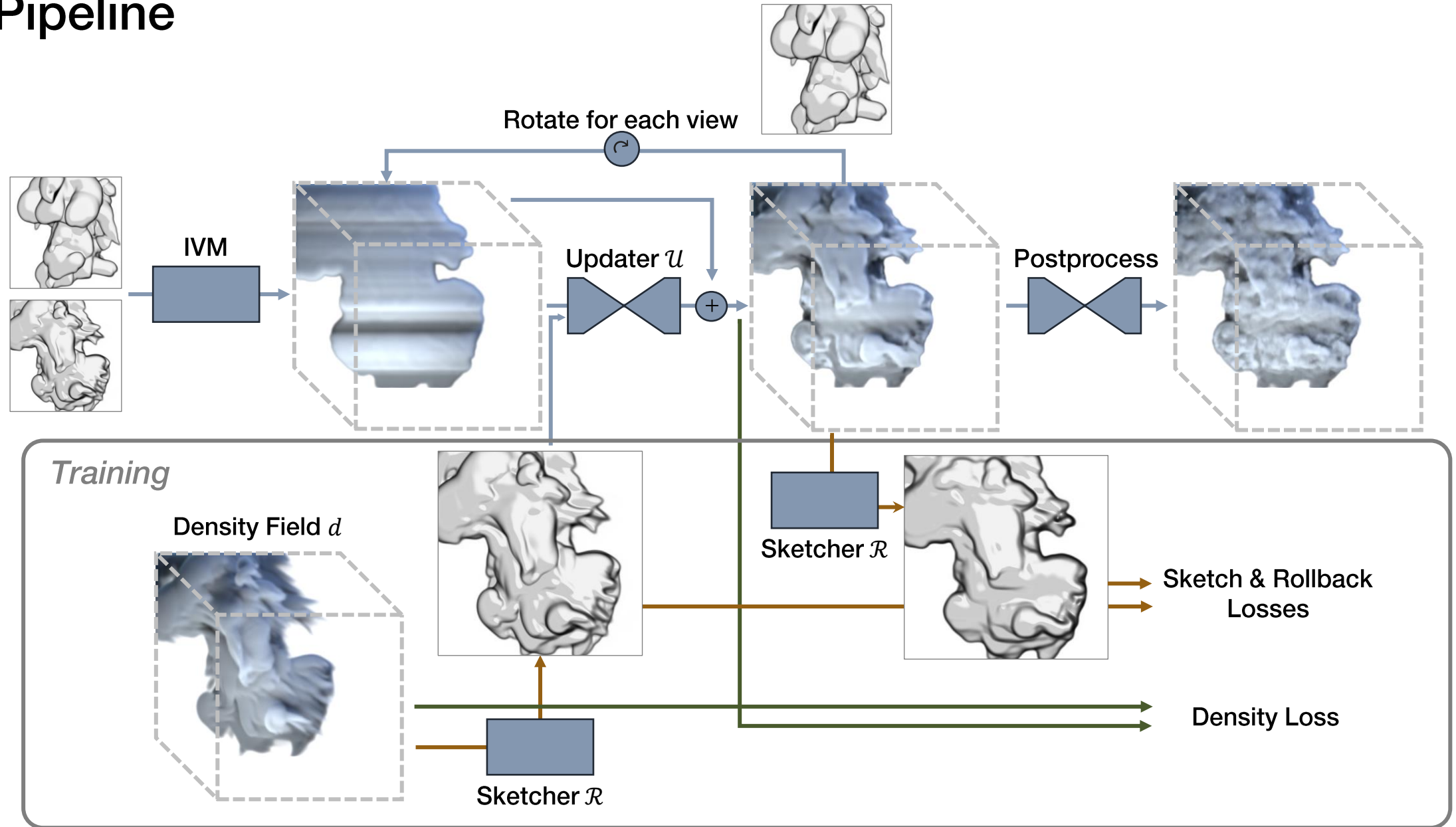


2. Multi-View Stability

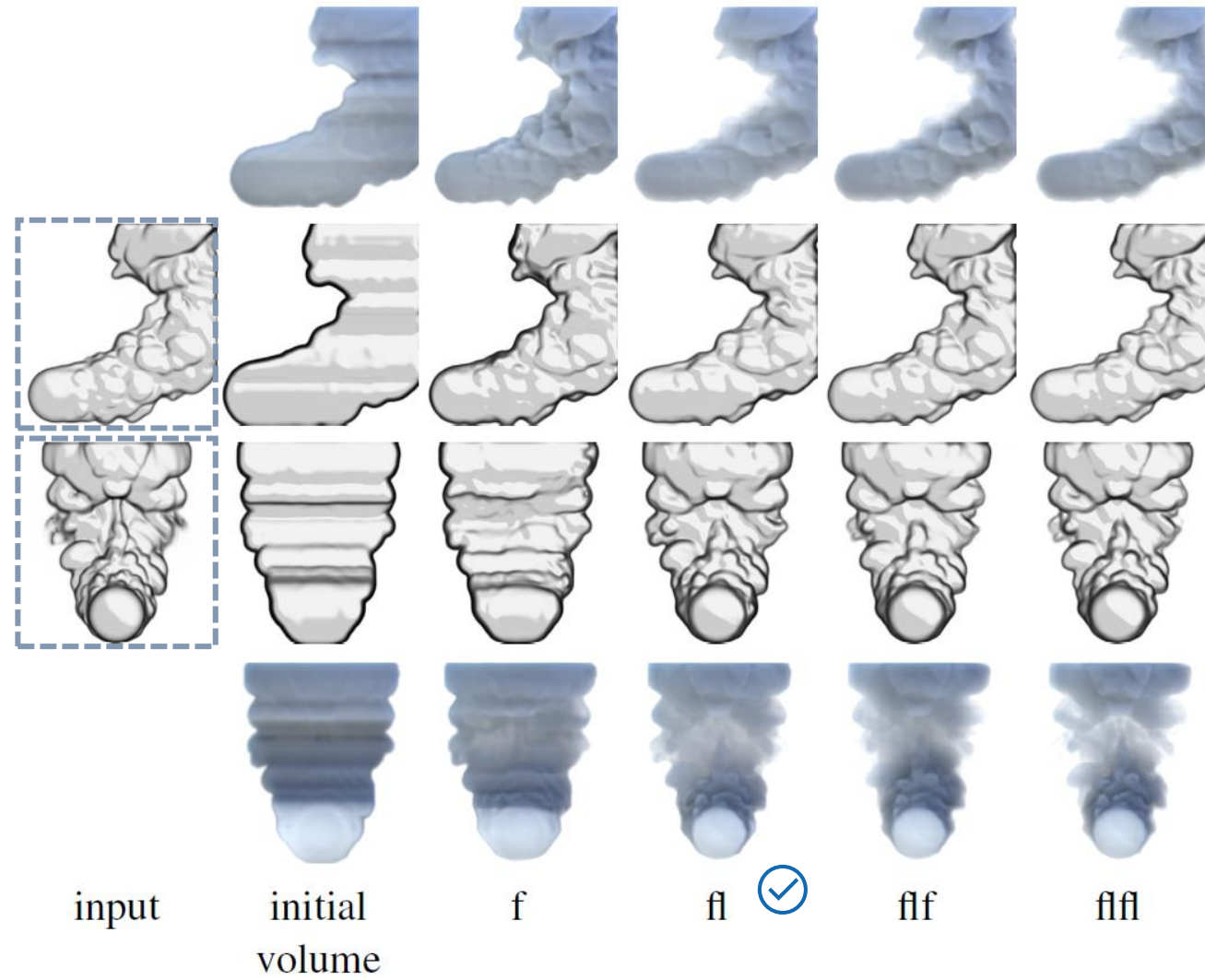
Pipeline



Pipeline



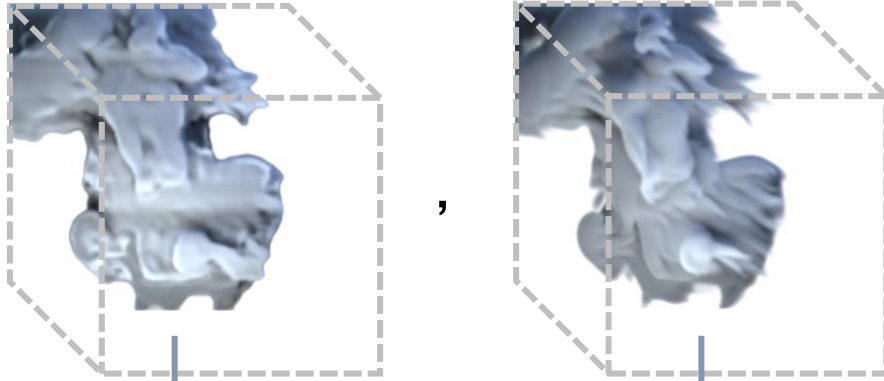
Pipeline



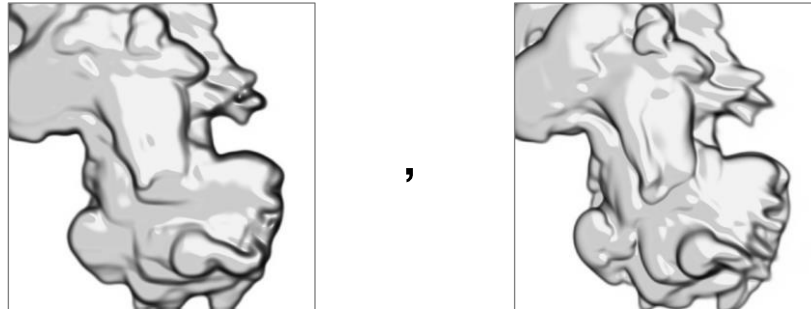
Loss Functions

Full Objective : (Density + Sketch + Depth Variation) Losses on **All Viewpoints**

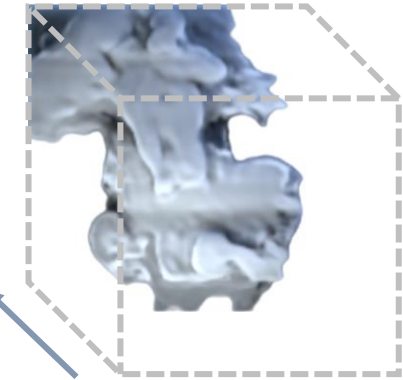
Density Loss (,)



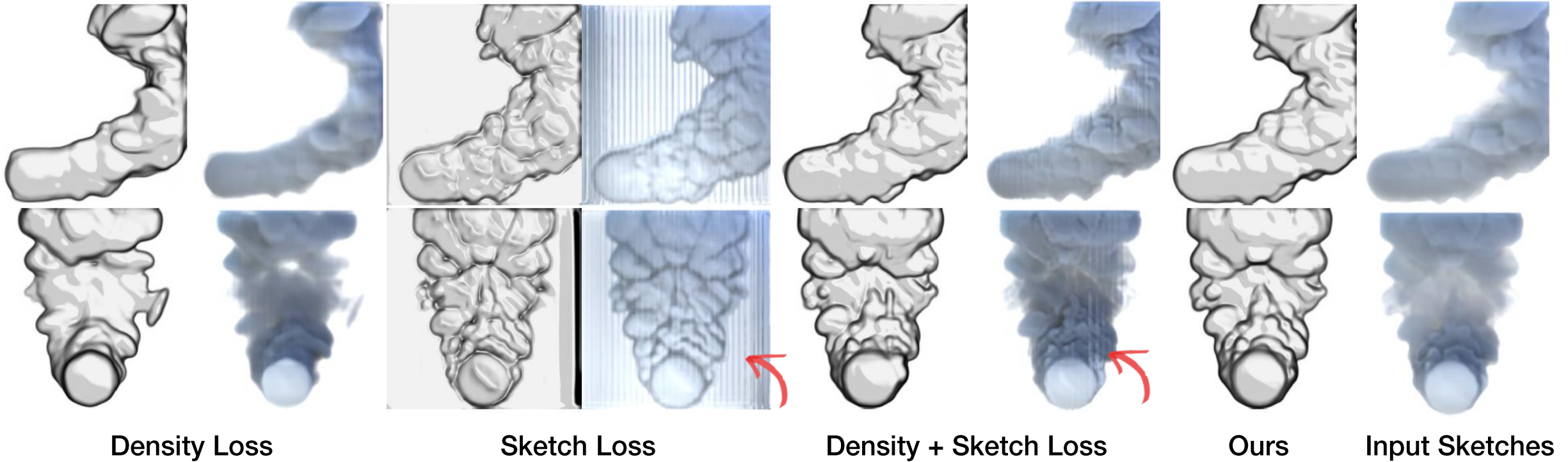
Sketch Loss (,)



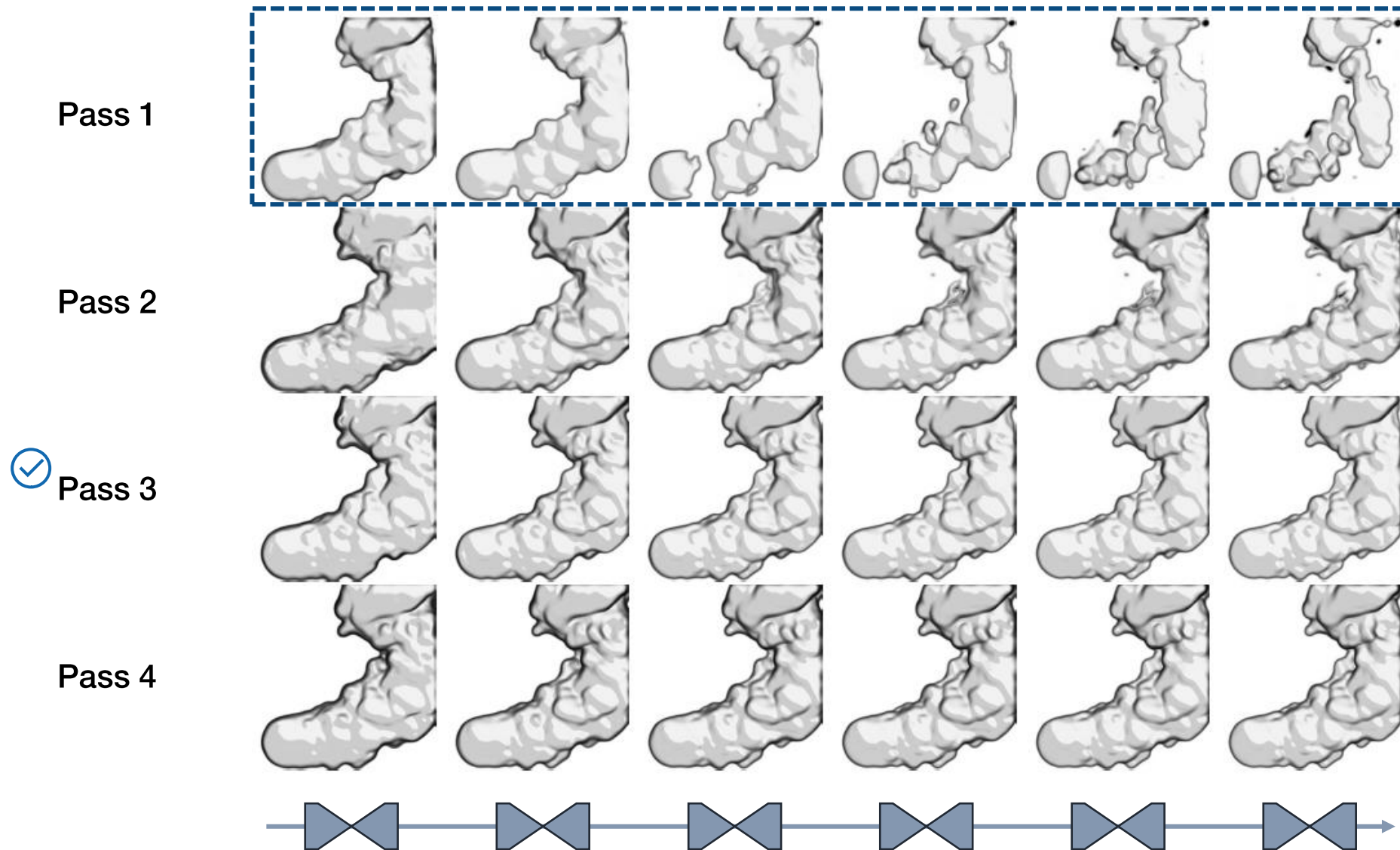
Depth
Variation
Loss
 $|\partial \hat{d} / \partial z|$



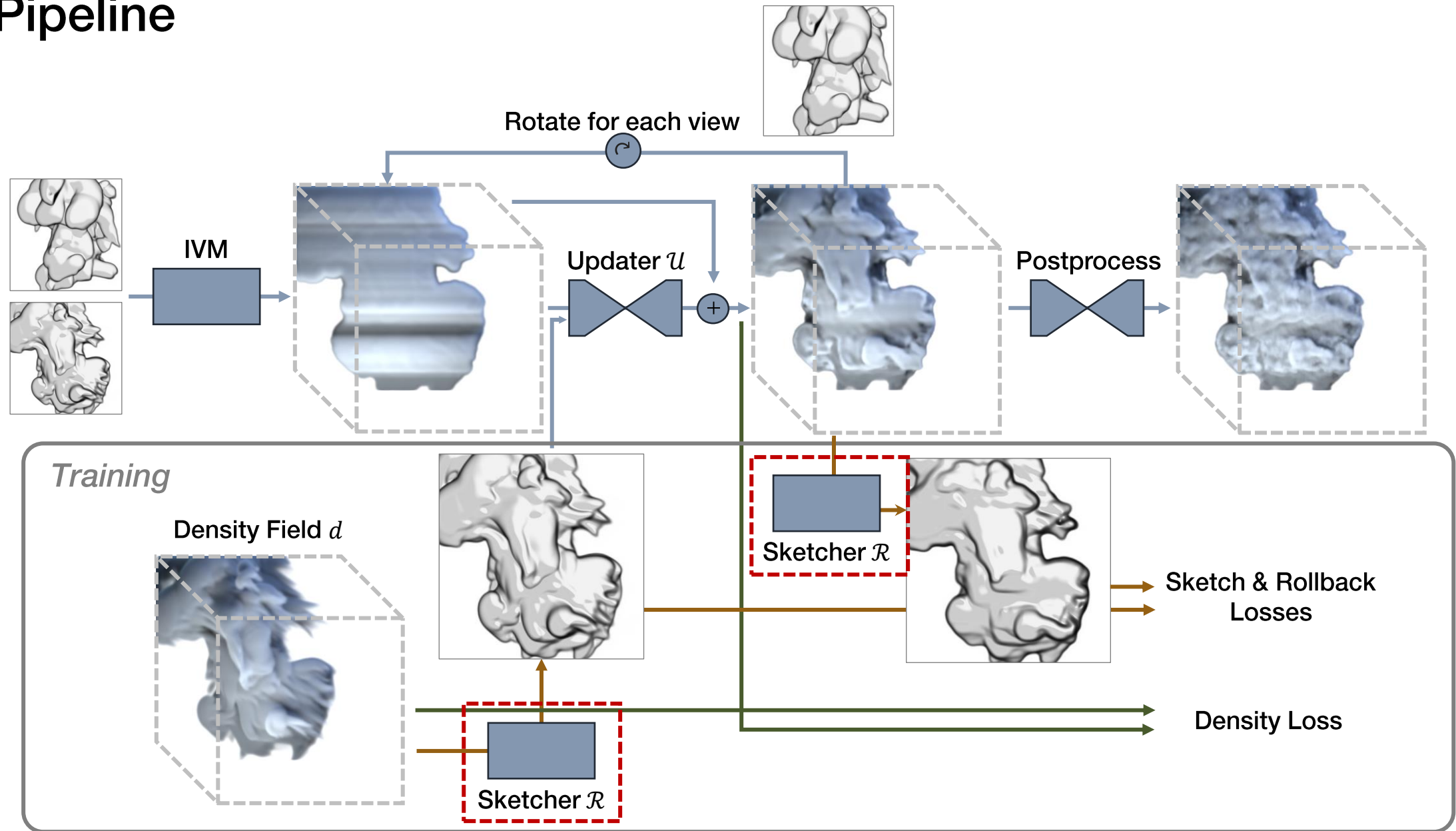
Loss Functions: Ablation Study



Loss Functions: Ablation Study



Pipeline



Differentiable Sketcher

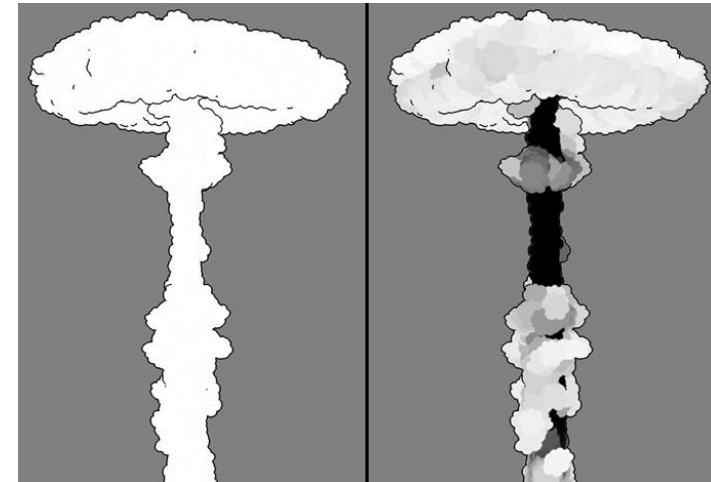
Suggestive Contours [De Carlo et al. 2003]



Contours from Mesh

Ours

Tracer Particles [Selle et al. 2004]



Differentiable Sketcher

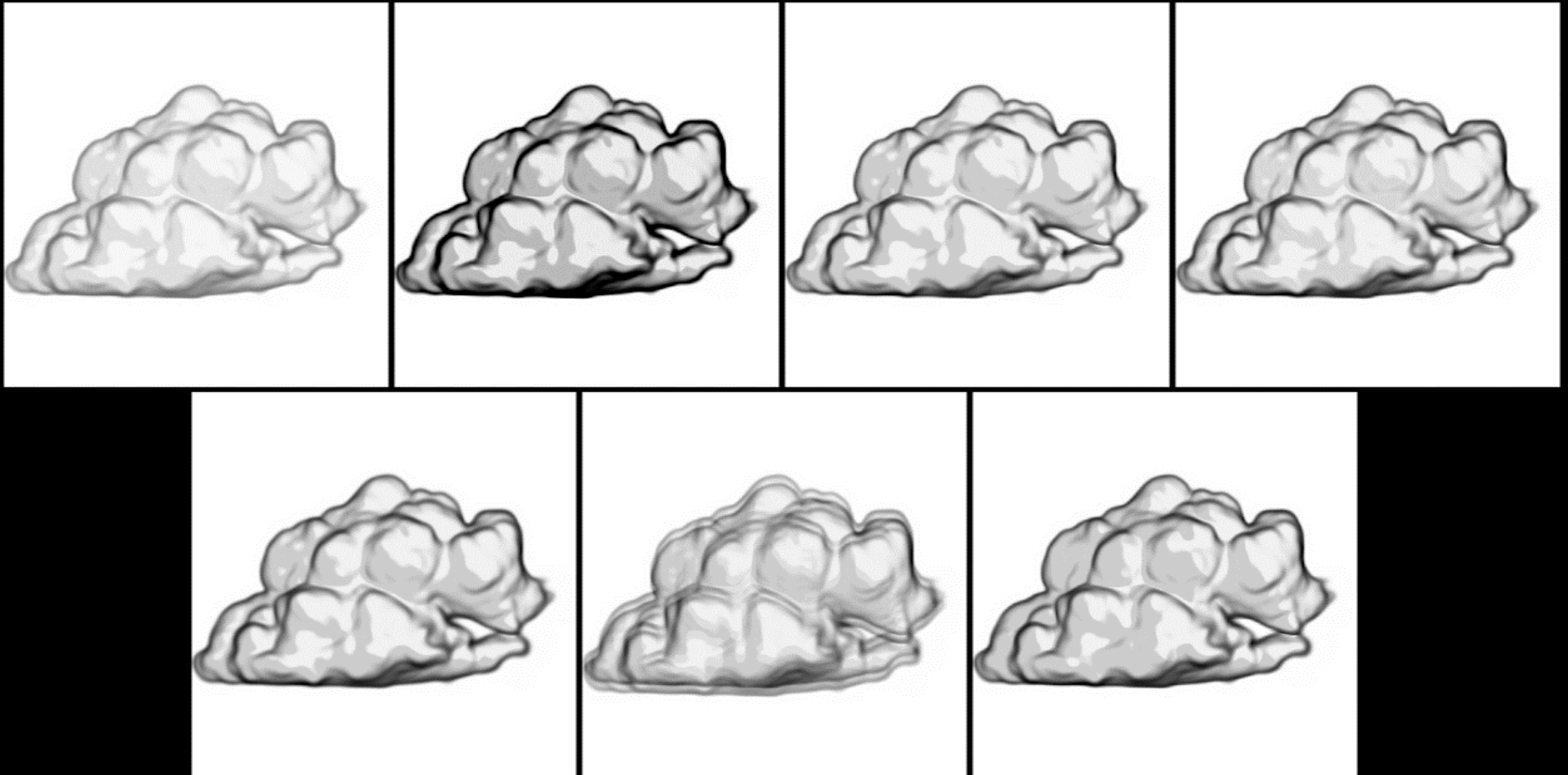


Density Field

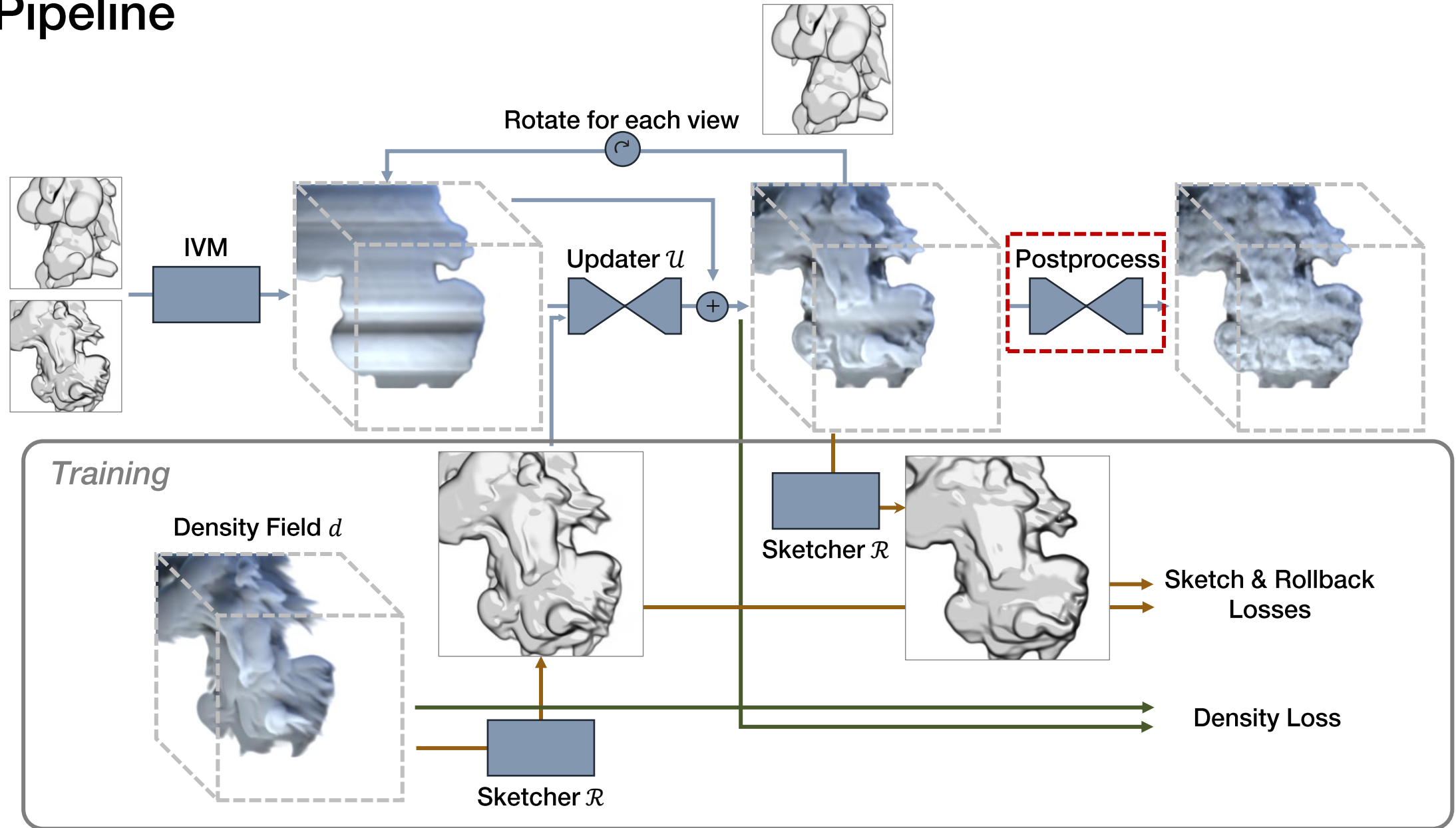


Sketch

Differentiable Sketcher: Augmentation

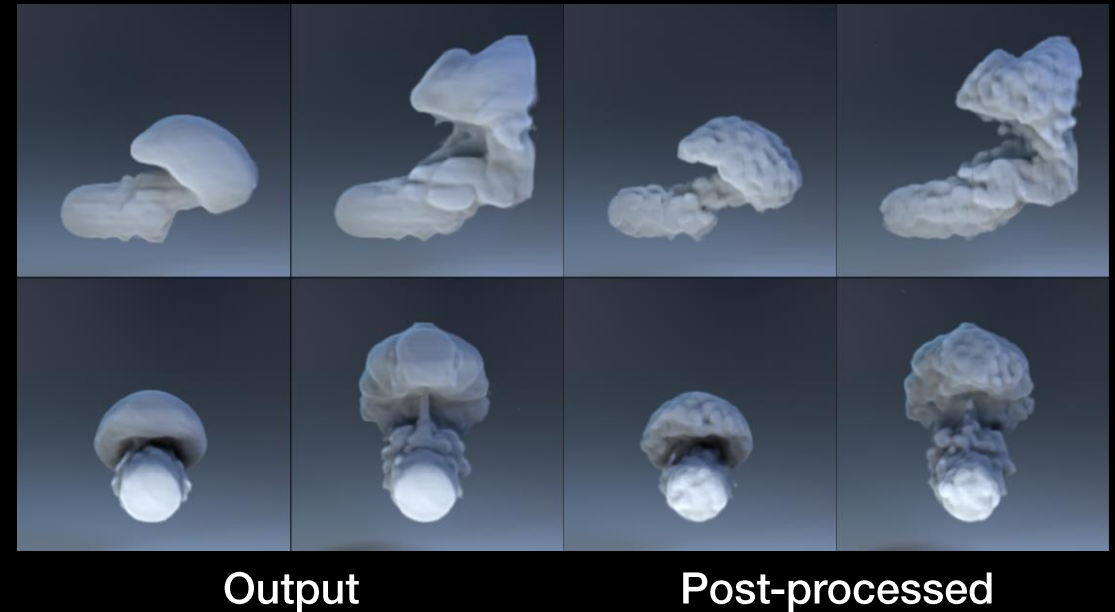


Pipeline



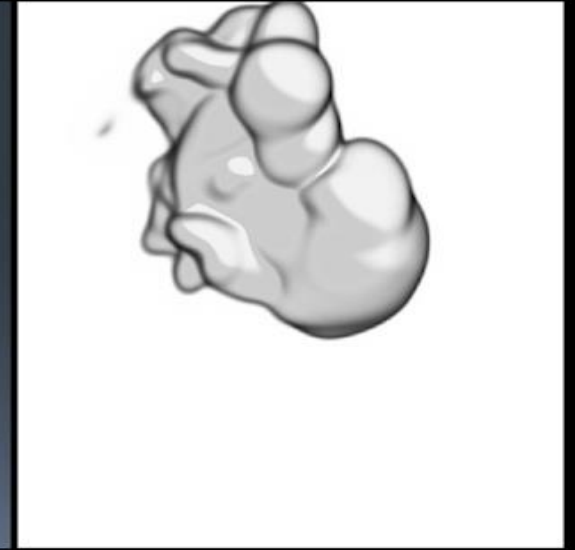
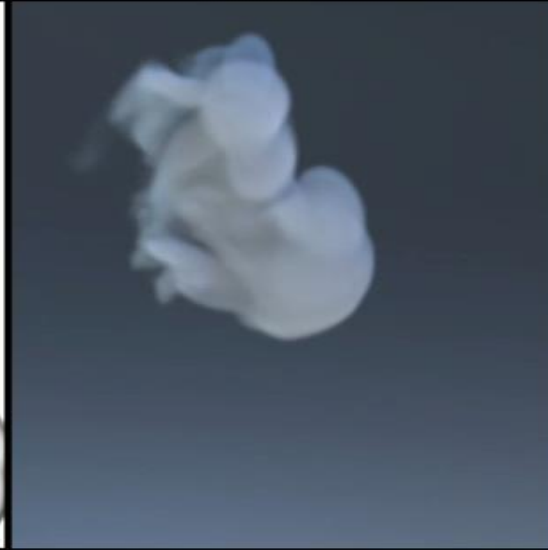
Post-Processing for Detail Synthesis

- Multi-Pass GAN [Werhan et al. 2019]
 - No temporal discriminator
- Model requires Velocity Field Input
 - Use curl-noise [Bridson et al. 2007] at test
 - Controllable by parameters

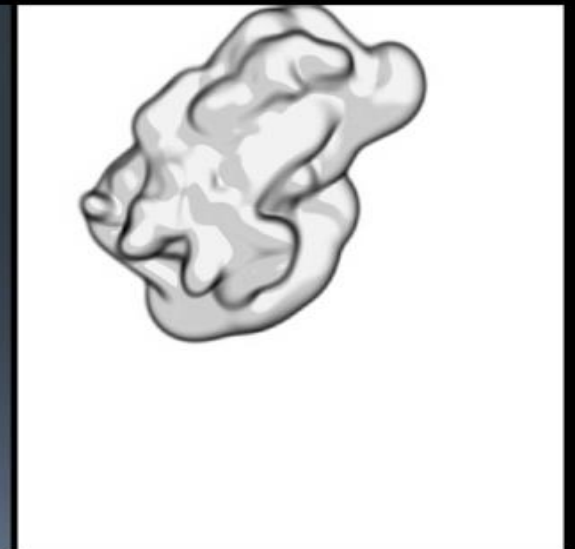


Training Dataset

Front



Left



No Source

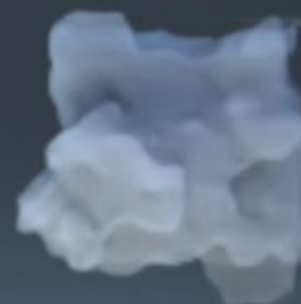
With Source

Training Result

Front



Left



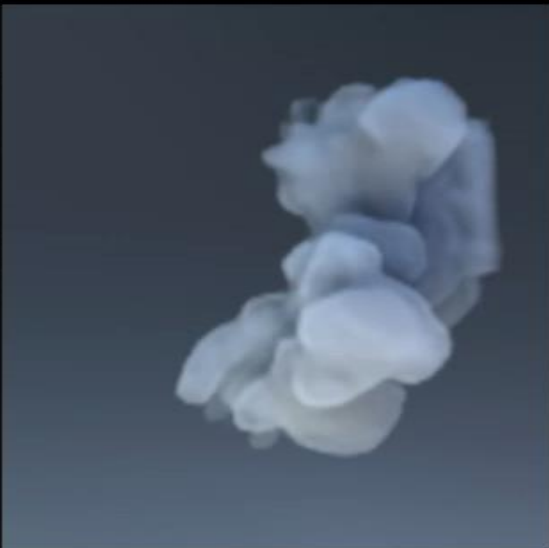
Input

Ours

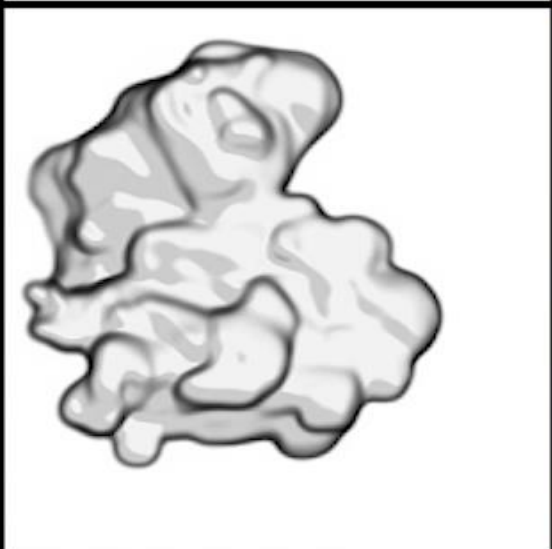
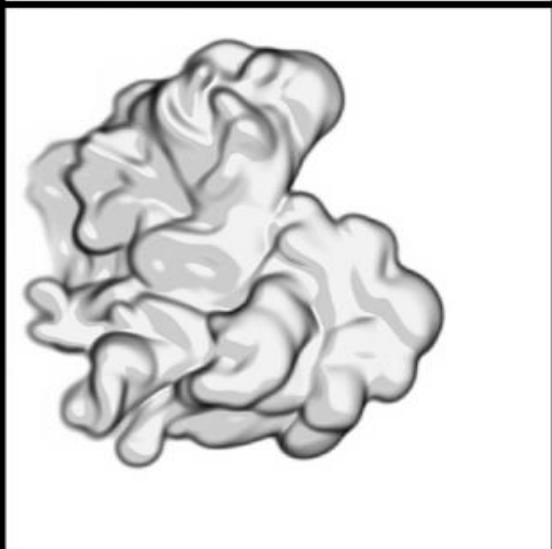
Ground Truth

Validation Result

Front



Left

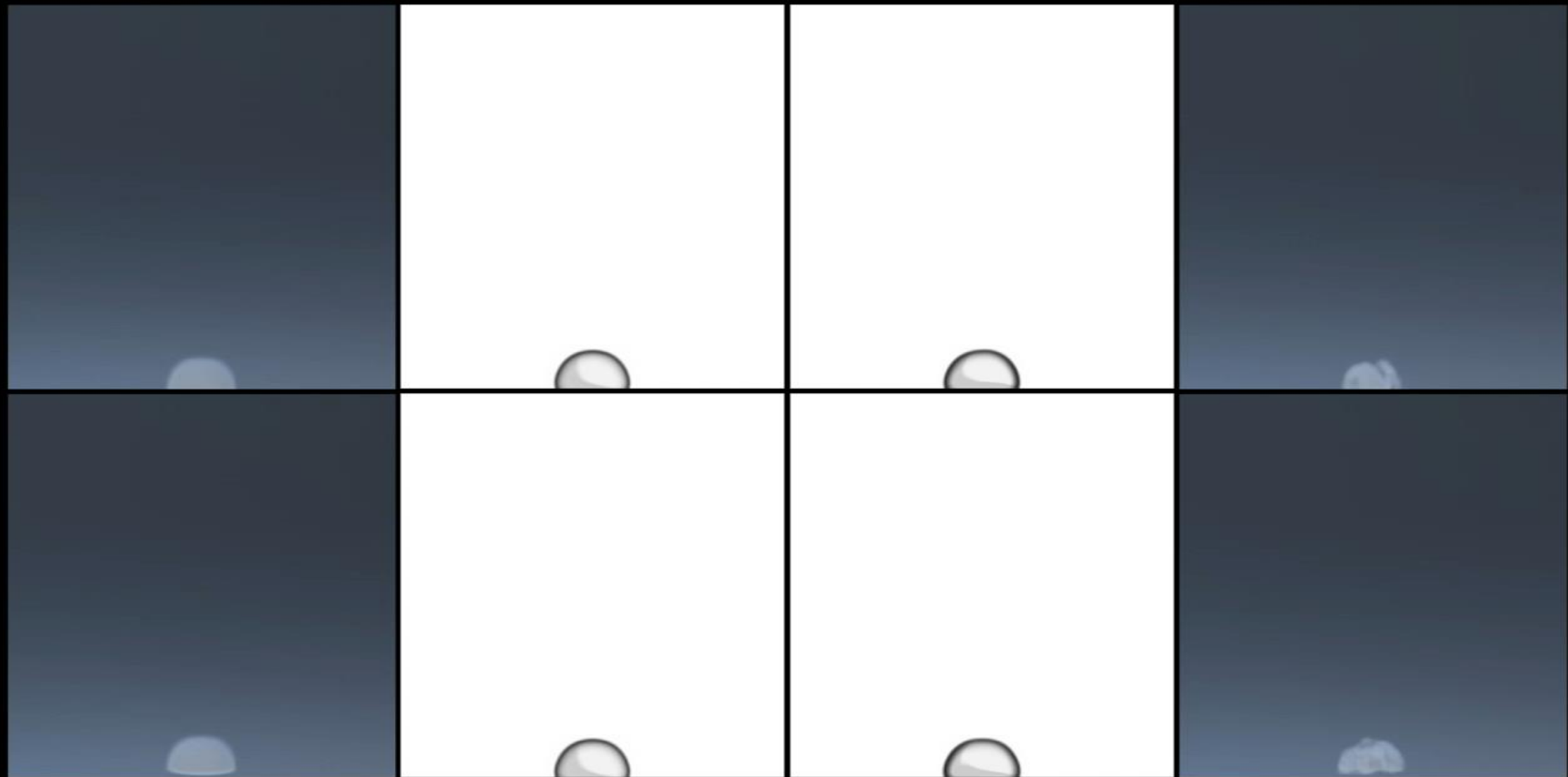


Input

Ours

Ground Truth

Synthetic Sketch Test: Fluid Simulation



Reference

Input

Ours

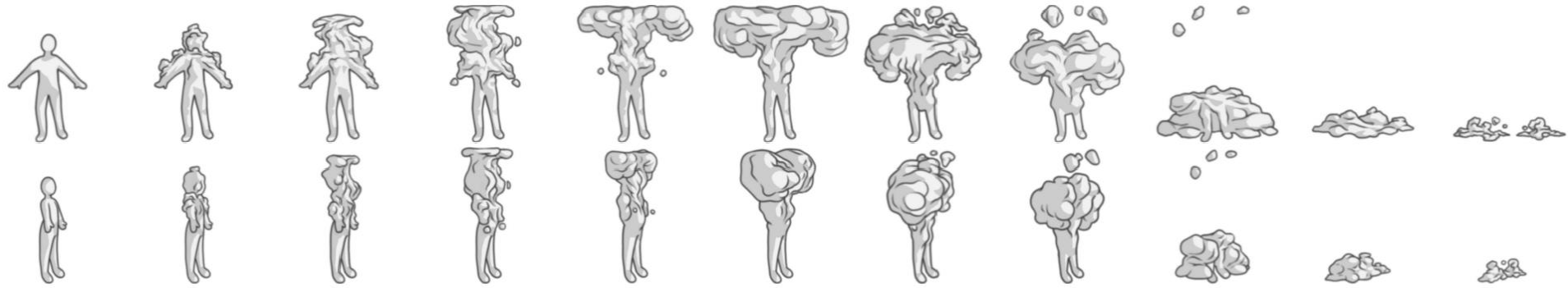
Synthetic Sketch Test: Animation Sequences



Input

Ours

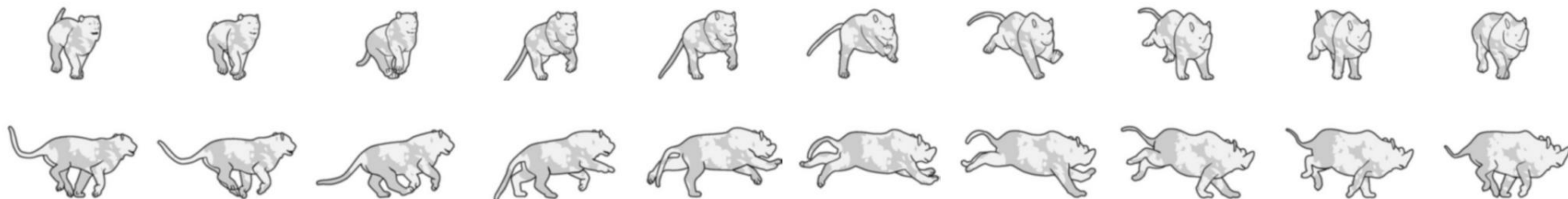
Artist Sketch Test



© Isabelle Hock

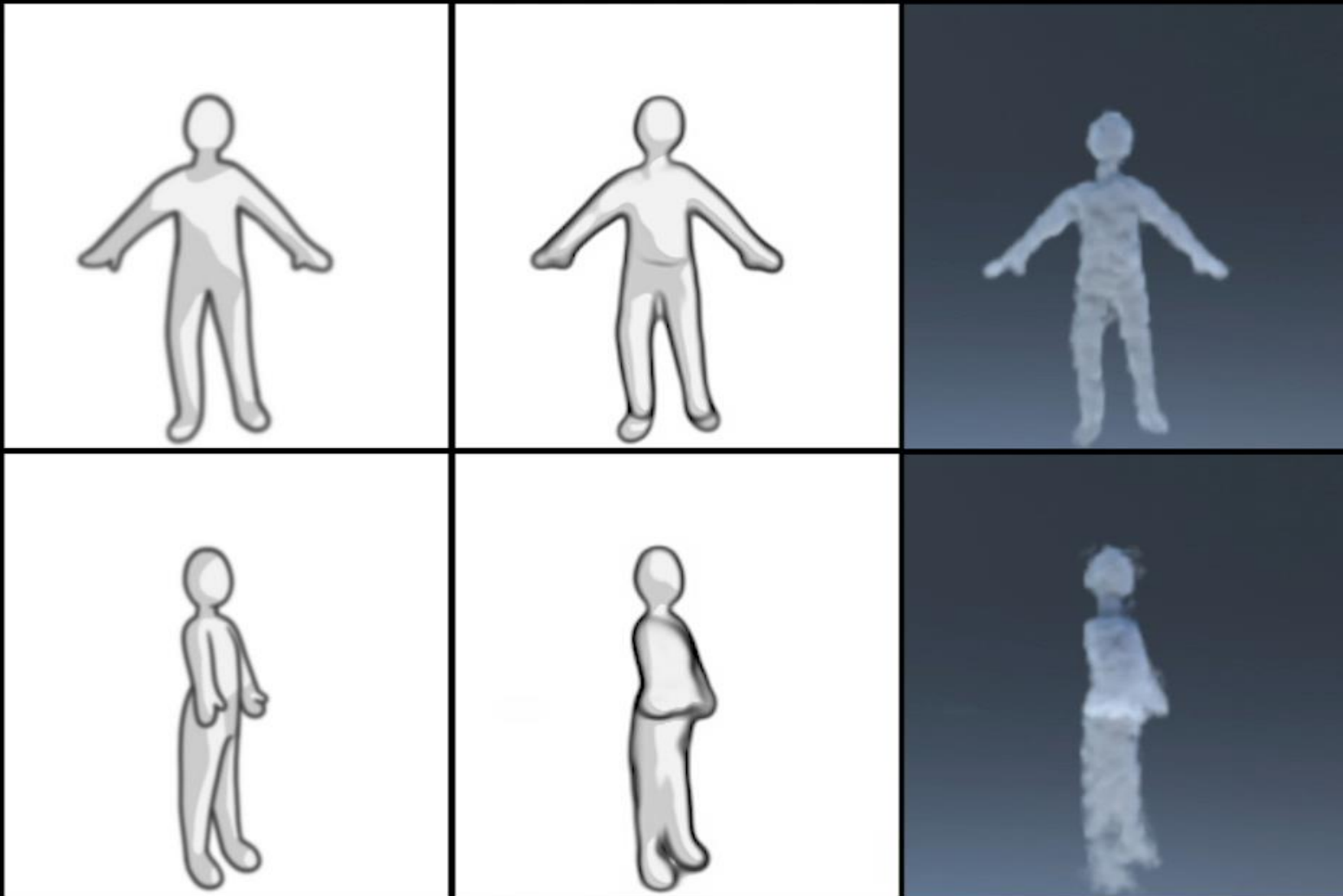


© Maurizio Nitti



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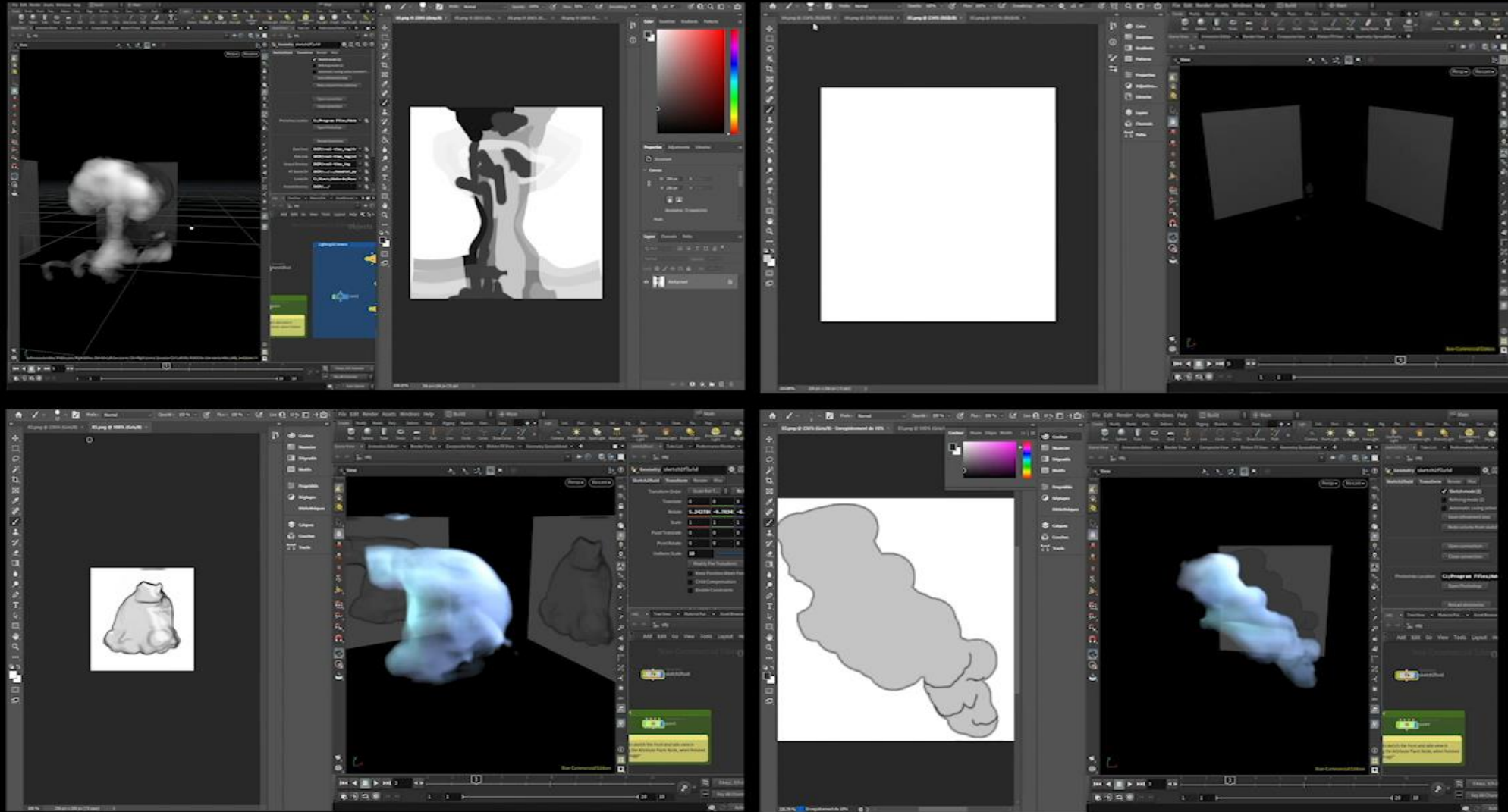
Artist Sketch Test



Input

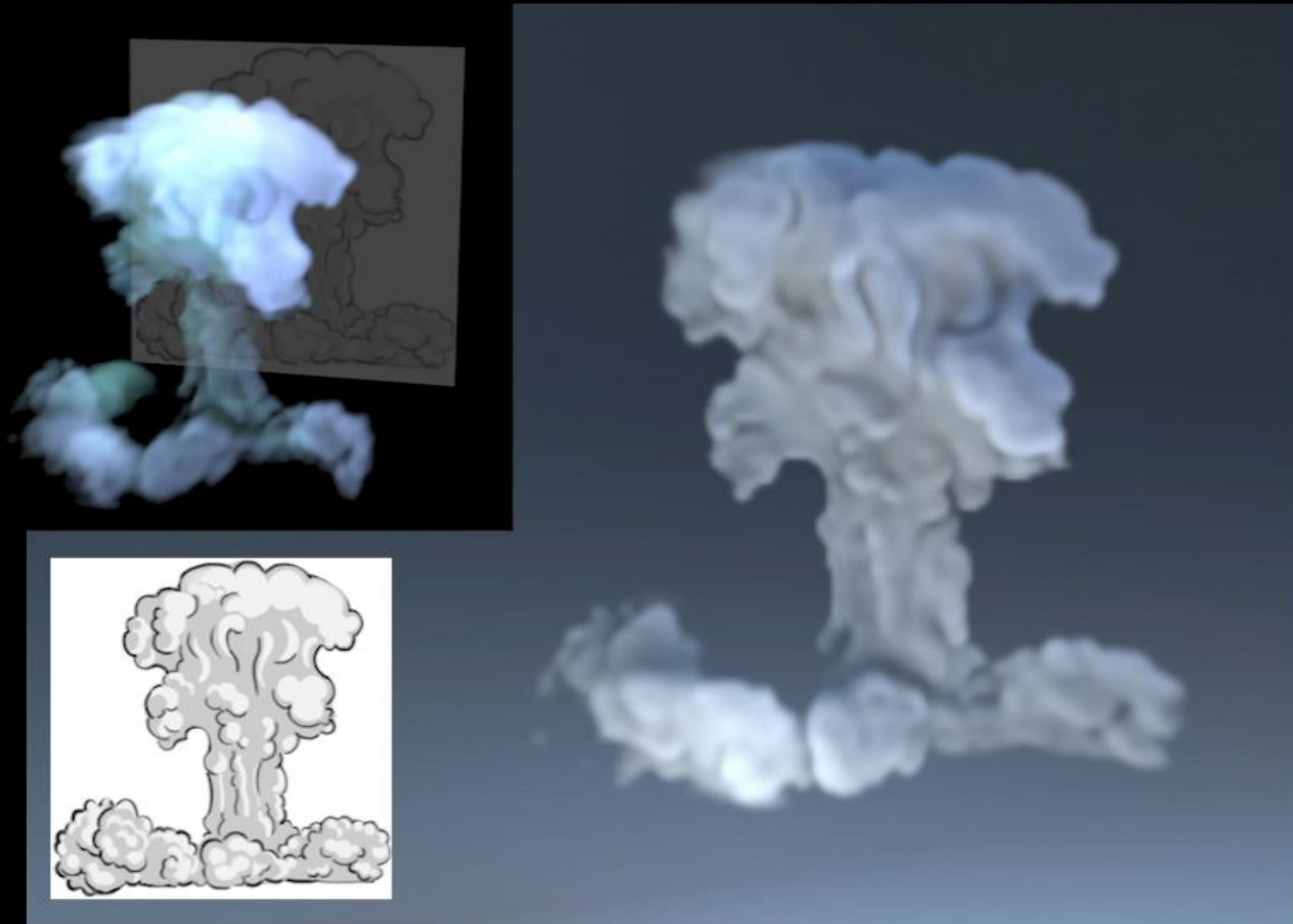
Ours

Interactive Authoring



Free sketch

Interactive Authoring

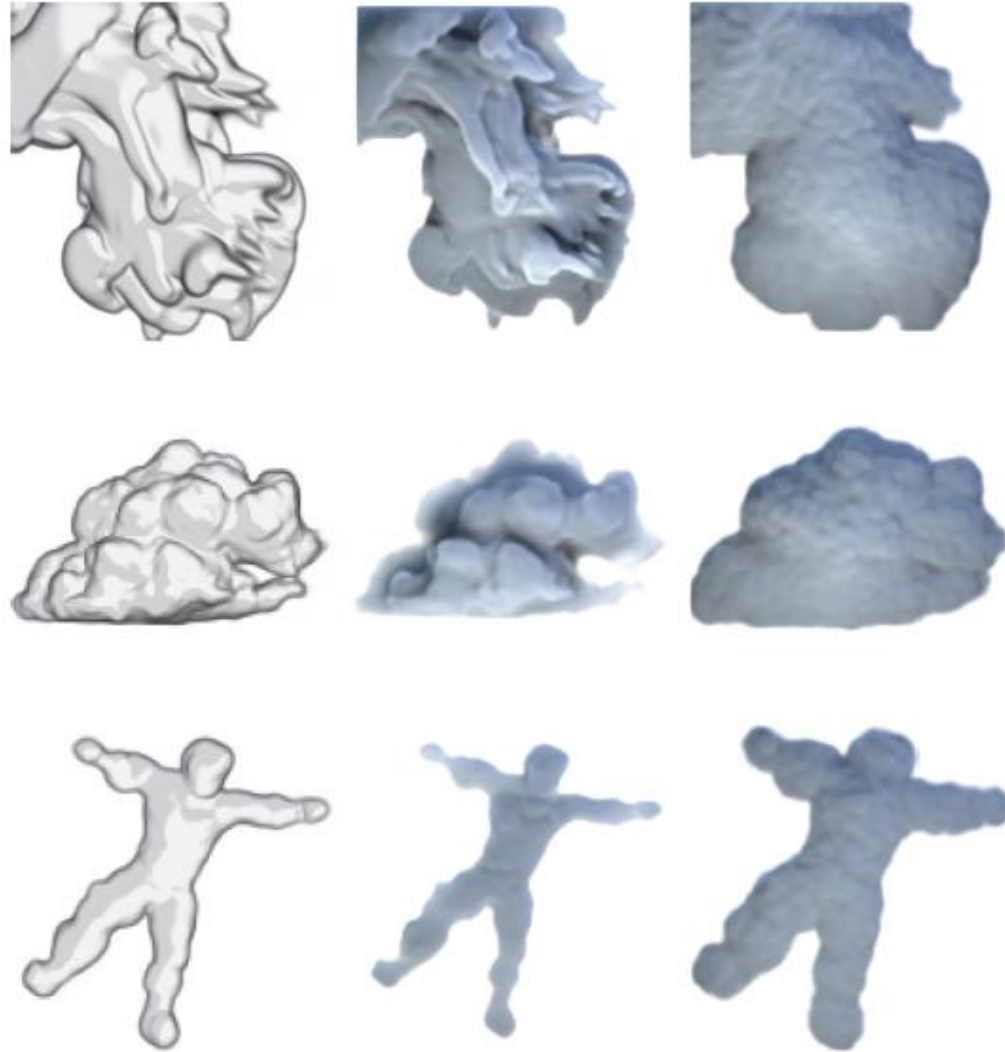


More results by each artist

Fluid Control Optimization



Evaluation: Comparison to [Stiver et al. 2010]



Input
Sketches

Ours

[Stiver et al. 2010]

Evaluation: User Study

User study (Ours [%], A [%], B [%])			
	Smoke data	Cloud	Character
Similarity	(86.8 , 13.2, 0)	(75.4 , 20.8, 3.8)	(84.9 , 11.3, 3.8)
Outer	(98.1 , 1.9, 0)	(85 , 7.5, 7.5)	(86.8 , 3.8, 9.4)
Inner	(100 , 0, 0)	(94.3 , 5.7, 0)	(90.6 , 7.5, 1.9)
Shading	(90.6 , 7.5, 1.9)	(86.8 , 7.5, 5.7)	(69.8 , 9.4, 20.8)
Reality	(34.6, 40.4 , 25)	(54.8 , 35.8, 9.4)	(52.8 , 32.1, 15.1)

Summary

- Real-Time, Iterative Refinement Method for Smoke Volumes from Sketches
- Differentiable Sketch Generator with Fluid Sketch Principles
- Carefully Designed Loss, Dataset, Augmentation for Robust Model
- Applications: Artist Sketch Test, Interactive Authoring, Animation Control

- Limited to Unscalable, Simplified Representation
- Arbitrary Drawing Styles are not Supported

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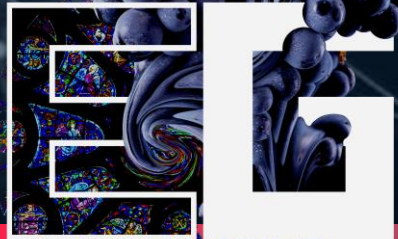
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