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Vidu4D: Single Generated Video to High-Fidelity 4D Reconstruction with Dynamic Gaussian Surfels

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- **Background:** Video generative models are receiving particular attention given their ability to generate realistic and imaginative frames. Moreover, these models are also observed to exhibit strong 3D consistency, significantly enhancing their potential to act as world simulators.
- **What challenges have been addressed?** How to accurately reconstruct 4D (i.e., sequential 3D) from a single generated video, addressing challenges related to non-rigidity and frame distortion.

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- **Basic 4D representation of Vidu4D:** The core is the proposed Dynamic Gaussian Surfels (DGS) technology. DGS optimizes time-varying warping functions, transforming Gaussian surfels (surface elements) from a static state to a dynamically warped state, a transformation that can precisely depict motion and deformation over time.

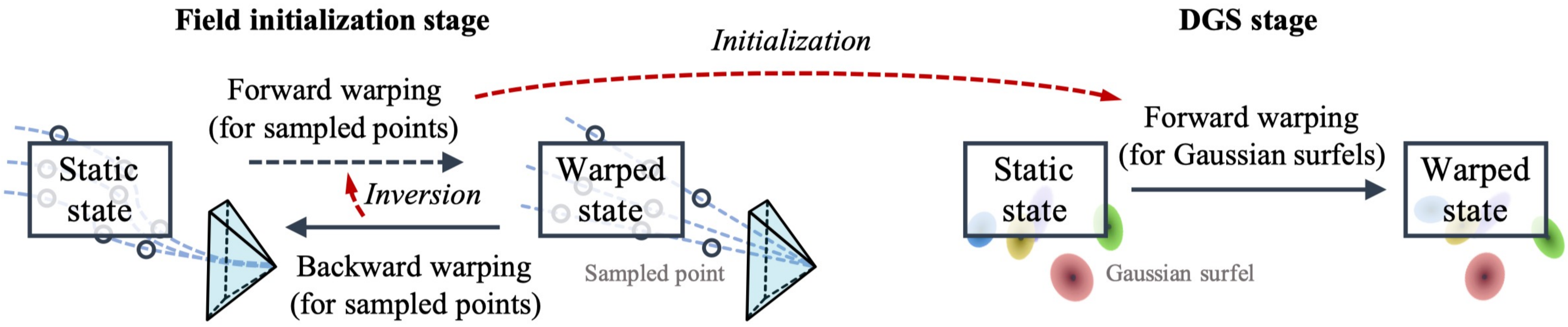

Illustration of the pipeline of Vidu4D, including the initialization stage and the DGS stage.

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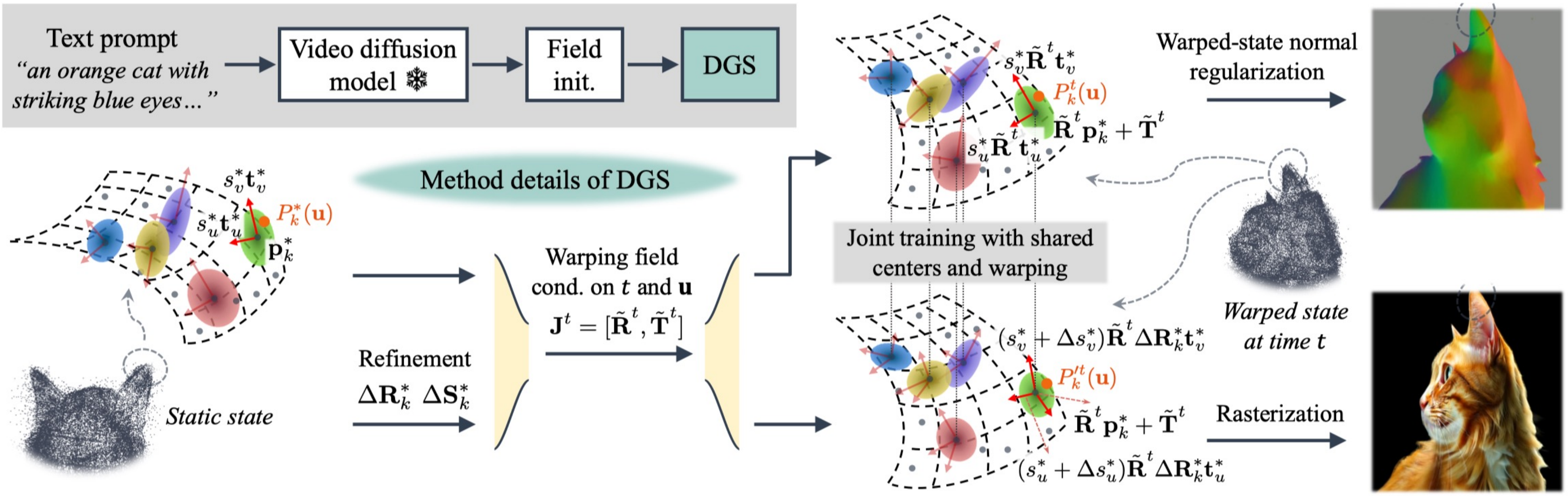
Dynamic Gaussian Surfels (DGS) captures high-quality dynamic textures and geometry.

- Part 1: Optimization of dynamic warping fields for Gaussian surfels

$$m_b^t = \left(P_k^*(\mathbf{u}) - \mathbf{c}_b^t\right)^\top \mathbf{Q}_b^t\left((P_k^*(\mathbf{u}) - \mathbf{c}_b^t\right), \quad \mathbf{w}^t = \sigma_{\text{softmax}}\left(m_1^t, m_2^t, \cdots, m_B^t\right)^\top \qquad \mathbf{J}^t = \mathcal{R}\left(\sum_{b=1}^{B} w_b^t \mathcal{Q}(\mathbf{J}_b^t)\right) \in \mathrm{SE}(3)$$

$$P_k^*(\mathbf{u}) = \mathbf{p}_k^* + s_u^*\mathbf{t}_u^* u + s_v^*\mathbf{t}_v^* v = [\mathbf{R}_k^*\mathbf{S}_k^* \quad \mathbf{p}_k^*]\,(u, v, 1, 1)^\top \qquad P_k^t(\mathbf{u}) = \mathbf{J}^t P_k^*(\mathbf{u}) = \left[\tilde{\mathbf{R}}^t\mathbf{R}_k^*\mathbf{S}_k^* \quad \tilde{\mathbf{R}}^t\mathbf{p}_k^* + \tilde{\mathbf{T}}^t\right](u, v, 1, 1)^\top$$



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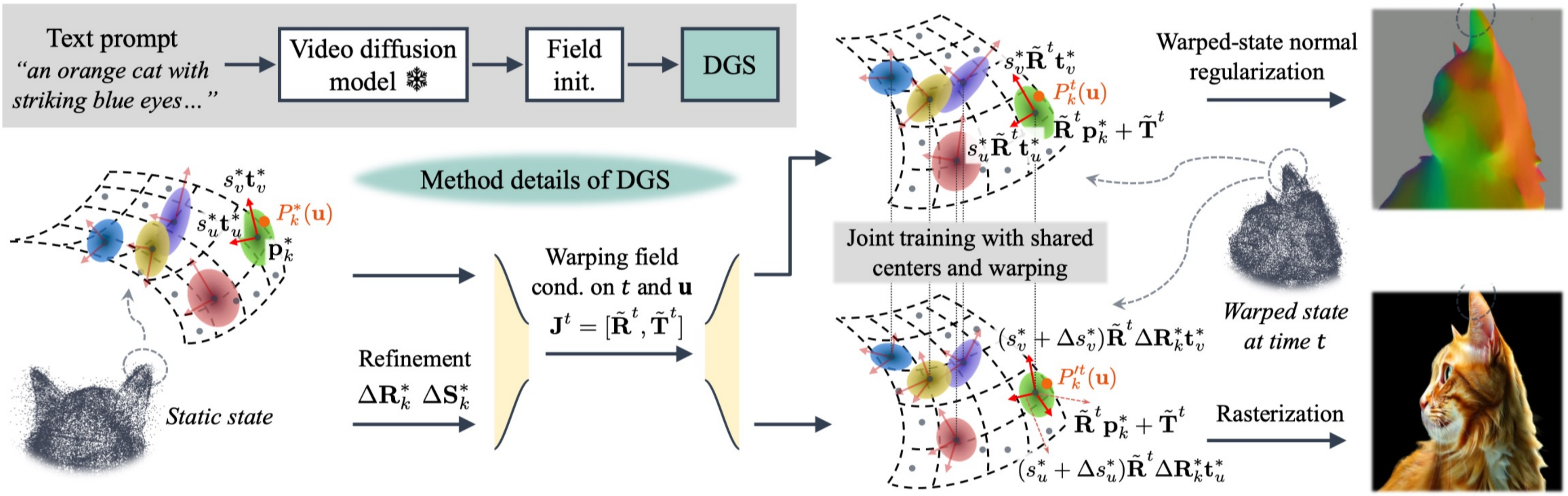
- Part 2: Geometric regularization of warping states based on continuous warping fields

$$\mathbf{J}_b^t = \mathcal{R}\big(\mathbf{MLP}(\gamma_b^t; \mathbf{u}, t)\big) \in \mathrm{SE}(3) \qquad \mathcal{L}_n = \sum_k \omega_k (1 - \mathbf{n}_k^\top \mathbf{N}^t), \quad \mathbf{N}^t(x, y) = \frac{\nabla_x \mathbf{p}^t \times \nabla_y \mathbf{p}^t}{|\nabla_x \mathbf{p}^t \times \nabla_y \mathbf{p}^t|}$$

- Part 3: Refinement during warping to enhance the capture of fine-grained appearance details

$$P_k'^t(\mathbf{u}) = \left[\tilde{\mathbf{R}}^t(\Delta\mathbf{R}_k^*\mathbf{R}_k^*)(\mathbf{S}_k^* + \Delta\mathbf{S}_k^*) \quad \tilde{\mathbf{R}}^t\mathbf{p}_k^* + \tilde{\mathbf{T}}^t\right](u, v, 1, 1)^\top$$



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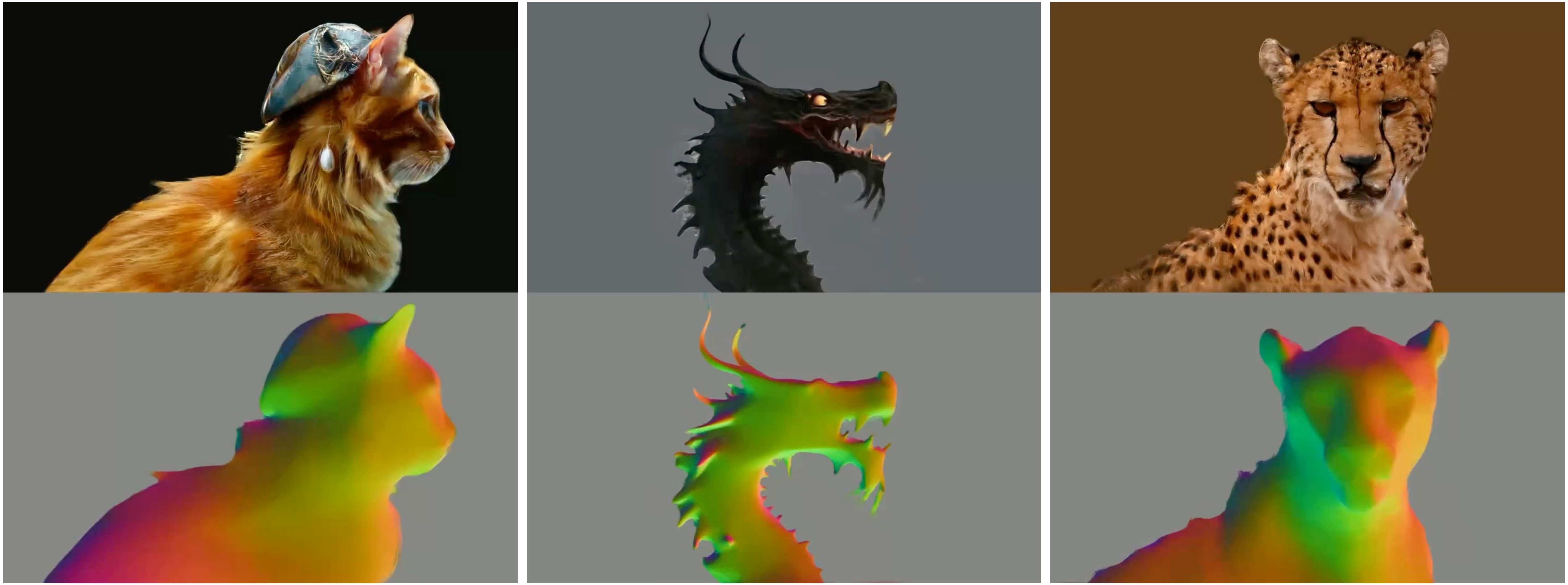
- Results of 4D generation:



- Our webpage is available at: https://vidu4d-dgs.github.io