GSplatLoc : Ultra-Precise Pose Optimization via 3D Gaussian Reprojection

https://spla-tam.github.io

Atticus Zhou, Atticus Zhou, Atticus Zhou, Atticus Zhou

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Abstract

we introduce GSplatLoc, a high-precision pose optimization method for unposed RGB-D cameras, utilizing a volumetric representation based on 3D Gaussian reprojection. This novel approach is specifically tailored for RGB-D data, enabling ultra-precise pose estimation through the integration of existing 3D Gaussian volumes and actual depth maps captured from varying perspectives. By optimizing the current pose against these models, GSplatLoc achieves rotational errors close to zero and translational errors within 0.01mm. This significant enhancement in pose accuracy is a hundredfold improvement over existing point cloud alignment algorithms for RGB-D pose estimation. Extensive comparisons demonstrate that GSplatLoc not only refines the accuracy of pose estimation but also enhances the robustness and fidelity of real-time 3D scene reconstruction, setting a new standard for SLAM applications in robotics and augmented reality.

1 Introduction

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2 Related Work

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3 Method

3.1 reprojection

Depth at a pixel i is represented by combining contributions from multiple Gaussian elements, each associated with a certain depth and confidence. Depth D_i can be expressed as[1]:

$$D_i = \frac{\sum_{n \leq N} d_n \cdot c_n \cdot \alpha_n \cdot T_n}{\sum_{n \leq N} c_n \cdot \alpha_n \cdot T_n}$$

d_n is the depth value from the n-th Gaussian, c_n is the confidence or weight of the n-th Gaussian,α_n is the opacity calculated from Gaussian parameters, T_n is the product of transparencies from all Gaussians in front of the n-th Gaussian.

The reprojection method utilizes the alignment of 2D Gaussian projections with observed depth data from an RGB-D camera. This involves adjusting the parameters of the Gaussians to minimize the discrepancy between the projected depth and the observed depth. The offset Δ_n and the covariance matrix Σ' are crucial for calculating the Gaussian weights α_n and their impact on reprojection accuracy.

3.2 loss

The loss function is designed to ensure accurate depth estimations and edge alignment, incorporating both depth magnitude and contour accuracy. It can be defined as:

$$L = \lambda_1 \cdot L_{\text{depth}} + \lambda_2 \cdot L_{\text{contour}}$$

where: $L_{\text{depth}} = \sum_i |D_i^{\text{predicted}} - D_i^{\text{observed}}|$ represents the L1 loss for depth accuracy, $L_{\text{contour}} = \sum_j |\nabla D_j^{\text{predicted}} - \nabla D_j^{\text{observed}}|$ focuses on the alignment of depth contours or edges, λ_1 and λ_2 are weights that balance the two parts of the loss function, tailored to the specific requirements of the application.

4 Experiments

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5 Conclusion

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[1] B. Kerbl, G. Kopanas, T. Leimkühler, and G. Drettakis, "3d gaussian splatting for real-time radiance field rendering," *ACM Transactions on Graphics*, vol. 42, no. 4, pp. 1–14, 2023, doi: 10.1145/3592433.