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Title: DARTS: Diffusion Approximated Residual Time Sampling forTime-of-flight Rendering in Homogeneous Scattering Media

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Source: ACM TRANSACTIONS ON GRAPHICS **Volume:** 43 **Issue:** 6 **Article Number:** 240 **DOI:** 10.1145/3687930 **Published Date:** 2024 DEC

Cited Reference Count: 55

Abstract: Time-of-flight (ToF) devices have greatly propelled the advancement ofvarious multi-modal perception applications. However, achieving accuraterendering of time-resolved information remains a challenge, particularly inscenes involving complex geometries, diverse materials and participatingmedia. Existing ToF rendering works have demonstrated notable results, yetthey struggle with scenes involving scattering media and camera-warpedsettings. Other steady-state volumetric rendering methods exhibit signif-icant bias or variance when directly applied to ToF rendering tasks. Toaddress these challenges, we integrate transient diffusion theory into pathconstruction and propose novel sampling methods for free-path distanceand scattering direction, via resampled importance sampling and offline tabulation. An elliptical sampling method is further adapted to provide con-trollable vertex connection satisfying any required photon traversal time. Incontrast to the existing temporal uniform sampling strategy, our method isthe first to consider the contribution of transient radiance to importance-sample the full path, and thus enables improved temporal path constructionunder multiple scattering settings. The proposed method can be integratedinto both path tracing and photon-based frameworks, delivering significantimprovements in quality and efficiency with at least a 5x MSE reductionversus SOTA methods in equal rendering time.

Accession Number: WOS:001367497900001

Language: English

Document Type: Article

Author Keywords: transient rendering; time-gated cameras; participating media; modeling and simulation

KeyWords Plus: MONTE-CARLO-SIMULATION

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Jiang, Haitian		0009-0006-8555-5284

Publisher: ASSOC COMPUTING MACHINERY

Publisher Address: 1601 Broadway, 10th Floor, NEW YORK, NY USA

Web of Science Index: Science Citation Index Expanded (SCI-EXPANDED)

Web of Science Categories: Computer Science, Software Engineering

Research Areas: Computer Science

IDS Number: N9M7R

ISSN: 0730-0301

eISSN: 1557-7368

29-char Source Abbrev.: ACM T GRAPHIC

ISO Source Abbrev.: ACM Trans. Graph.

Source Item Page Count: 14

Open Access: hybrid, Green Submitted

Output Date: 2025-04-20

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