Adaptive Incident Radiance Field Sampling and Reconstruction Using Deep Reinforcement Learning

Yuchi Huo, Rui Wnag, Ruzhang Zheng, Hualin Xu, Hujun Bao, Sung-eui Yoon
KAIST and CAD&CG
Global Illumination

Filtering
• Animation, preview …

Path Guiding
• Design, Physical Simulation, Data Generation …
Global Illumination

Filtering
- Animation, preview …

Path Guiding
- Design, Physical Simulation, Data Generation …
Filtering V.S. Path Guiding

<table>
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<th>min</th>
<th>KPCN</th>
<th>Ours</th>
<th>Reference</th>
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30 | 60 | 120 | min
Path Guiding – A Sampling Problem
Path Guiding – A Sampling Problem

Evaluate

QUALITY NETWORK

Sample

Reward

high reward if Reconstruction $\rightarrow$ GT

RECONSTRUCTION NETWORK
Training R- and Q-networks

Dataset Ground Truth

R-network

Target
Output

Reconstruction

Reward Generation

Reward

Dataset Feature

Q-network

Input
Target

Input
Radiance Field Reconstruction using Deep Learning

Reconstruction:
- To guide path tracing
- To generate preview
- Others
  - Extremely sparse samples
  - Memory/computation overhead
  - Hard to find ground-truth
Radiance Field Reconstruction using Deep Reinforcement Learning

**Q-network:** Adaptive sampling and refining the radiance field, trained by DRL

**R-network:** Reconstruct 4D radiance field in both image and direction spaces
Adaptive Sampling and Refining

Q-network:
Adaptive Sampling and Refining

(a) Sampling in Direction Space

\[ \theta = 0 \]

\[ \cos^{-1} \sqrt{0.5} \]

\[ 0.5\pi \]

\[ \varphi = 0 \]

\[ 2\pi \]
Adaptive Sampling and Refining

(a) Sampling in Direction Space

\[ \theta = 0, \cos^{-1} \sqrt{0.5}, 0.5\pi \]

\[ \varphi = 0, 2\pi \]

(b) Quality values of adaptive actions

Q-network Prediction

Refine or Resample

R-network
Adaptive Sampling and Refining

(a) Sampling in Direction Space

\[ \theta = 0 \]

\[ \cos^{-1} \sqrt{0.5} \]

\[ 0.5\pi \]

\[ \phi = 0 \]

\[ 2\pi \]

(b) Quality values of adaptive actions

Q-network Prediction

Refine or Resample

(c) Adaptive sampling and refining in Direction Space

R-network
R-network

• Explore 4D radiance field in:
  • Image–direction
  • Direction–image
  • Direction
  • Image
R-network

- Image-direction network:

Image Space Features: Normal, Radiance …

Direction Space Feature Maps

∀i ∈ Γ
Q-network

- Actions:
  - Refinement
  - Resampling

- Q-value (reward):
  - Decline of the Difference between GT and R-network output
Q-network

\[ \mathcal{Q} \]

\[ F_d^+ = \text{CONVs (3 layers)} \]

\[ G^+ \]

\[ \forall j \in \Psi \]

\[ R^+ \]

\[ \Rightarrow \]

\[ H^+ \]

\[ \Rightarrow \]

\[ Q \text{-value of Refining} \]

\[ Q \text{-value of Resampling} \]

\[ \forall i \in \Gamma \]

\[ \forall j \in \Psi \]

Image Space Features:
Normal, Radiance, Hierarchies …

Direction Space Feature Maps

FCs

(4 layers)
Results (path guiding)

(b) GMM  rMSE 0.0268
(c) SD-tree  rMSE 0.0041
(d) Ours  rMSE 0.0022
(e) Reference
Results (path guiding)

- GMM
- SD-tree
- Ours
- Reference

(b) GMM rMSE 0.149
(c) SD-tree rMSE 0.150
(d) Ours rMSE 0.003
(e) Reference
Results (path guiding)

GMM | SD-tree
---|---
Ours | Reference

(b) GMM rMSE 0.0.00072
(c) SD-tree rMSE 0.0201
(d) Ours rMSE 0.00035
(e) Reference
Results (direct filtering)
Results (Filtering v.s. Path Guiding)

1

rMSE 0.0027
rMSE 0.023
rMSE 0.0017
rMSE 0.013
rMSE 0.00079
rMSE 0.0013

KPCN Ours

2

rMSE 0.00066
rMSE 0.00068
rMSE 0.00061
rMSE 0.00042
rMSE 0.00056
rMSE 0.00017

KPCN Ours

8

rMSE 0.00066
rMSE 0.00068
rMSE 0.00061
rMSE 0.00042
rMSE 0.00056
rMSE 0.00017

Reference

min KPCN Ours min
THANK YOU