Under the Shadow: Exploiting Opacity Variation for Fine-grained Shadow Detection

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NEURAL INFORMATION PROCESSING SYSTEMS

Motivation

Existing works consider shadow regions as binary masks, often leading to imprecise detection results and suboptimal performance for scene understanding applications.

Input Image | Binary Shadow Mask | Continuous Shadow Mask

Fine-grained Shadow Detection Problem

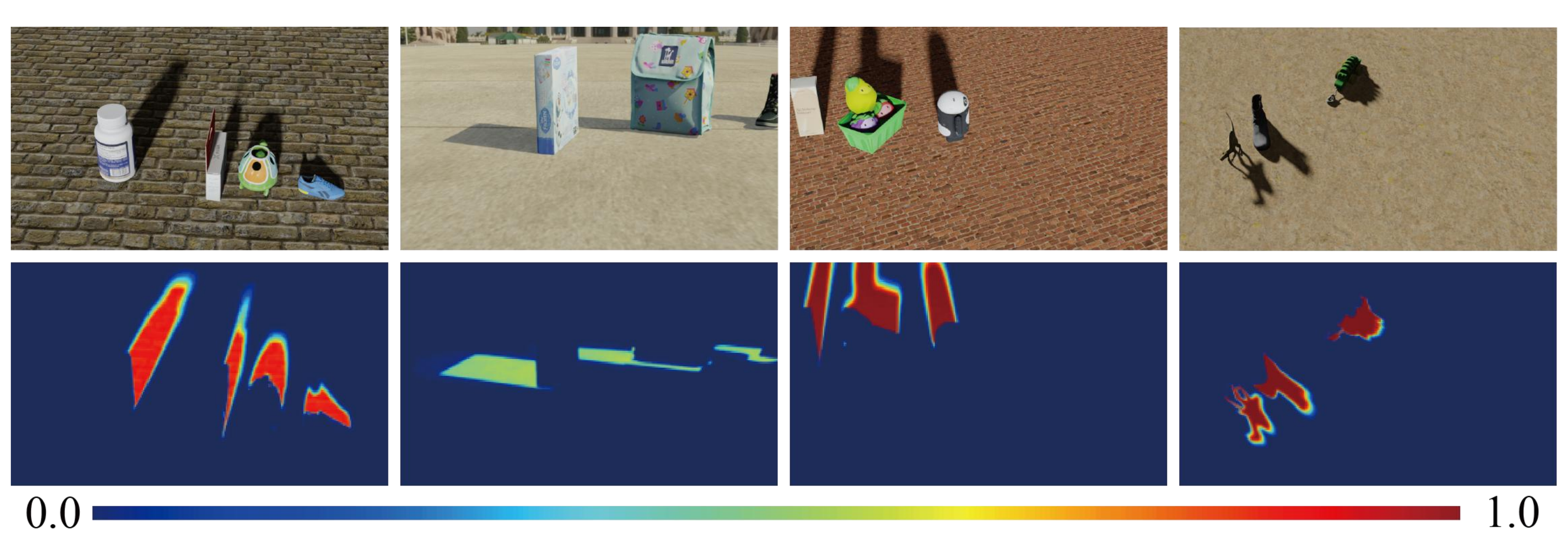
- Given an input image, our goal is to predict a continuous opacity mask representing the shadow region.
- The continuous shadow opacity mask is useful in various downstream scene understanding applications.

Contributions

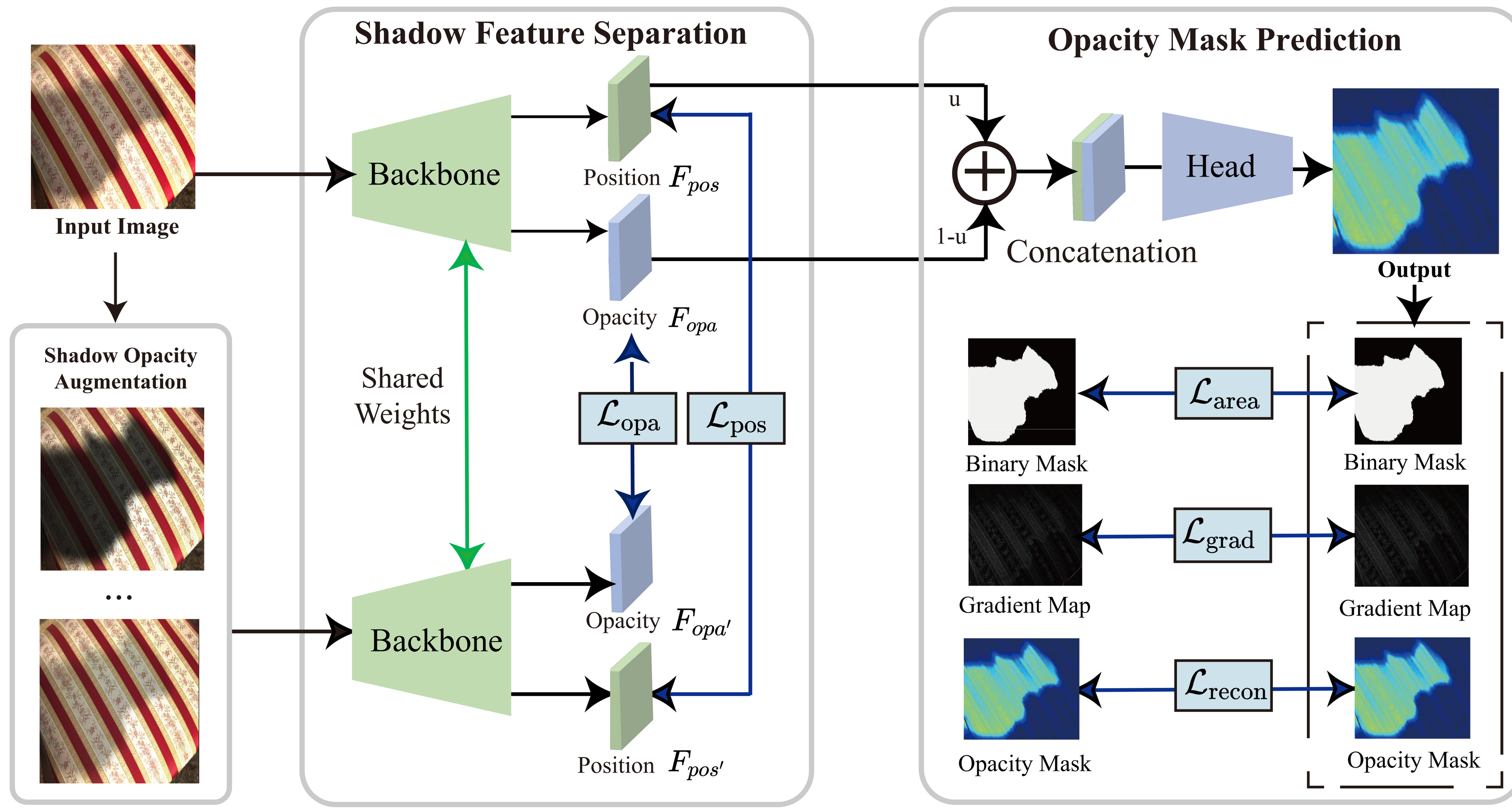
- We make the first attempt to investigate fine-grained shadow detection by exploiting opacity variations.
- We propose a new shadow detection method by explicitly capturing shadow position and opacity characteristics, and construct a new FSD dataset.
- Results show that our method can predict fine-grained shadow characteristics and enable various applications.

Fine-grained Shadow Detection Dataset

The FSD dataset contains 2,653 scenes with different objects, scenes, and light source properties. Each scene contains varied fine-grained shadow characteristics.



Approach



Shadow Opacity Augmentation Module
SOA aims to leverage shadow opacity characteristics by performing shadow augmentation through randomly altering the opacity of shadow regions.

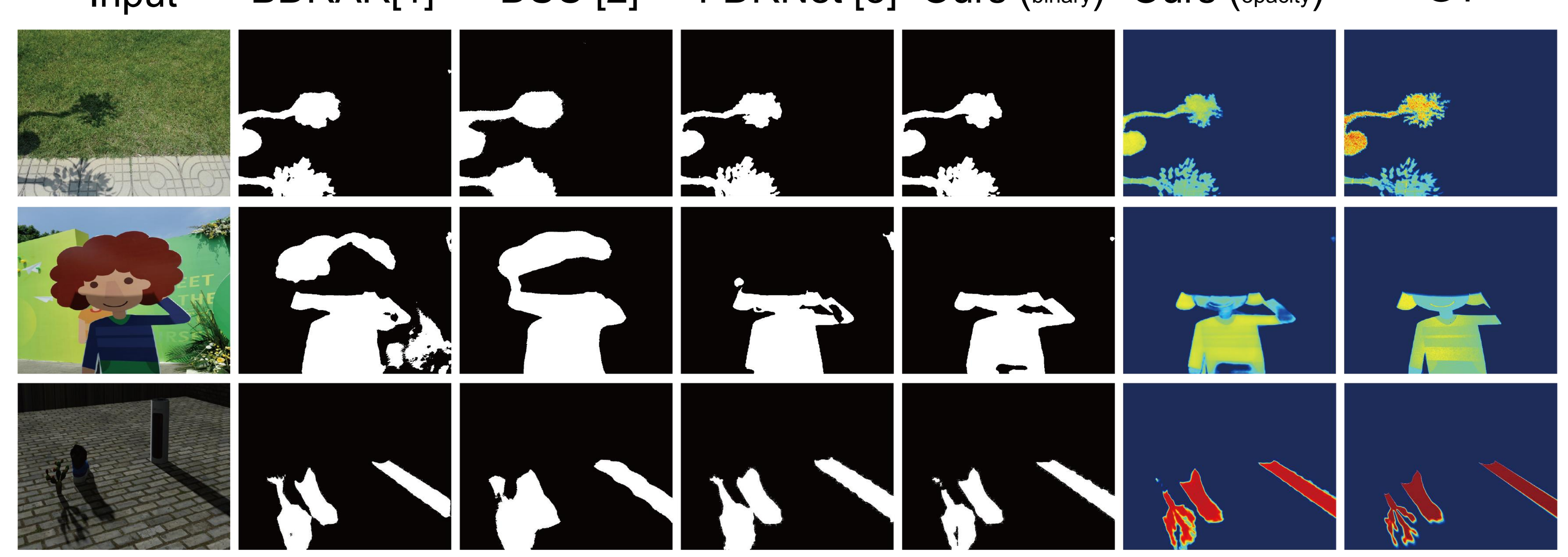
Shadow Feature Separation Module
SFS aims to extract the position and opacity features separately from an input image pair of the same scene with different shadow opacities.

Opacity Mask Prediction Module
OMP aims to fuse positions and the opacity feature to predict the fine-grained shadow detection result.

Experiments

Qualitative & Quantitative Evaluations

Input | BDRAR[1] | DSC [2] | FDRNet [3] | Ours (binary) | Ours (opacity) | GT



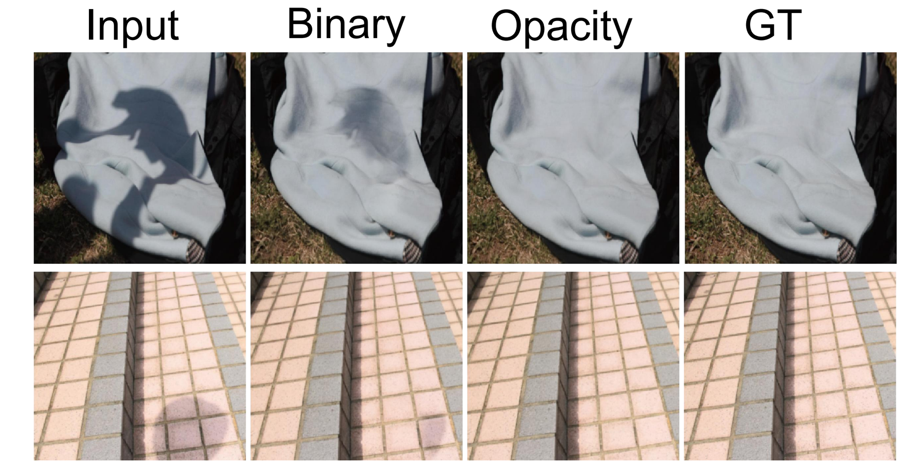
Metric	BDRAR [1]	DSC [2]	FDRNet [3]	Ours
BER	2.69	3.42	1.55	**1.32**
Shadow	**0.50**	3.85	1.22	0.96
Non Shad.	4.87	3.00	1.88	**1.67**

Shadow Editing Application

Input | Object-Shadow | Background Editing | Foreground Editing

Shadow Removal Application

Input | Binary | Opacity | GT



MASK	PSNR	SSIM	MAE
FDRNet	37.31	0.985	5.04
GT	37.78	0.985	3.44
Ours	**42.06**	**0.995**	**3.32**

3D Reconstruction Application

We employ the opacity map (instead of the binary map) of shadow regions, as the guidance for 3D reconstruction [4].

Mask	Bunny	Cube
FDRNet (Binary Shadow Mask)	0.00957	0.01074
Ours (Continuous Shadow Mask)	**0.00531**	**0.00777**

Reference

[1] Lei Zhu et al. Bidirectional feature pyramid network with recurrent attention residual modules for shadow detection. In ECCV, 2018.

[2] Xiaowei Hu et al. Direction-aware spatial context features for shadow detection and removal. In IEEE TPAMI, 2019.

[3] Lei Zhu et al. Mitigating intensity bias in shadow detection via feature decomposition and reweighting. In ICCV, 2021.

[4] Kushagra Tiwary et al. Towards learning neural representations from shadows. In ECCV, 2022.