Visibility Constrained Wide-band Illumination Spectrum Design for Seeing-in-the-Dark

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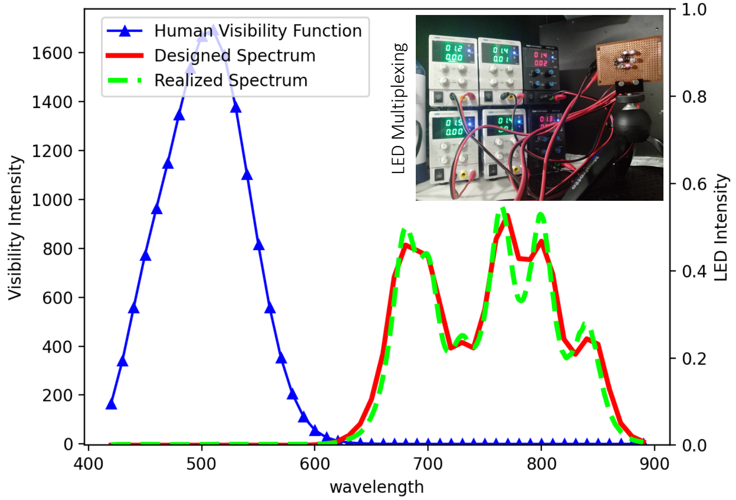
Thumbnail

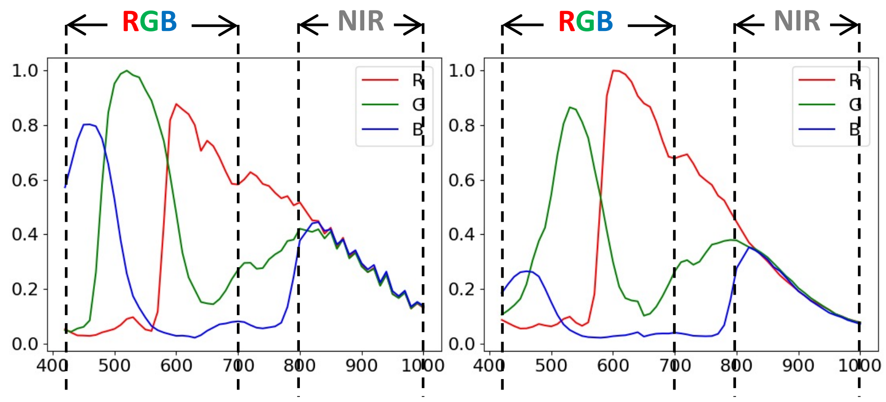
- In this paper, we try to design the optimal illumination spectrum for Seeing-in-the-dark.
- We propose a paradigm that incorporates the Human Vision System into the design process.
- A Visibility Constrained Spectrum Design (VCSD) model is proposed to formulate and assure the visibility level of certain spectra during the optimization process.
- We also contribute a wide-band hyperspectral image dataset.



NIR2RGB Ours Ground Trut

Motivation

- Two threads for Seeing-in-the-dark:
  - Low-light enhancement adopts RGB information but has generalization issues due to unknown illumination.
  - NIR2RGB uses known NIR illuminants but unstable due to intrinsic ambiguity: lack of RGB information.
- The best solution for complete darkness would be using *known RGB-NIR illumination*.
- However, The illuminant may become visible to human eyes when getting nearer to visible range.



Wavelength Range	<700nm	700-800nm	800-900nm
Performance			
Visibility Issue			

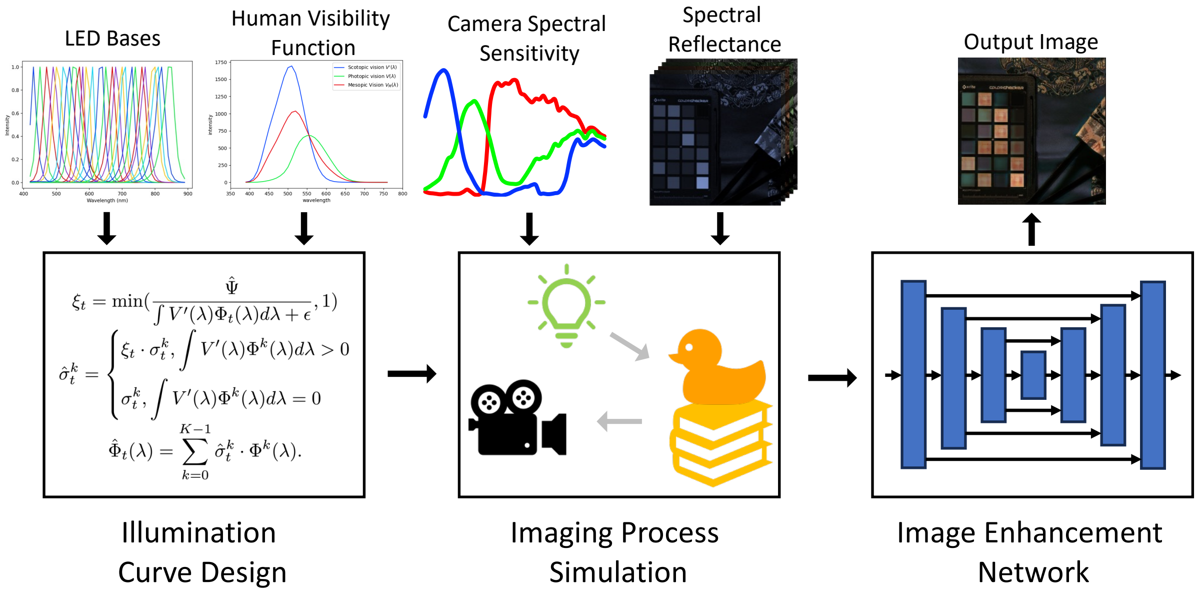
Motivation

- We want an *<u>RGB-NIR curve</u>* that cover as much information as possible and *<u>does not violate the visibility criteria</u>*!
- TO DO THIS, WE:
  - quantify and incorporate the human vision system.
  - formulate the visibility level of certain illumination spectrum during the optimization process.
  - simulate the hyperspectral imaging and the noise process.
  - contribute a wide-band hyperspectral image dataset.

Wavelength	<700nm	700-800nm	800-900nm	Designed Curve
Performance	🙂	😐	🙁	🙂
Visibility Issue	🙁	😐	🙂	🙂

Method

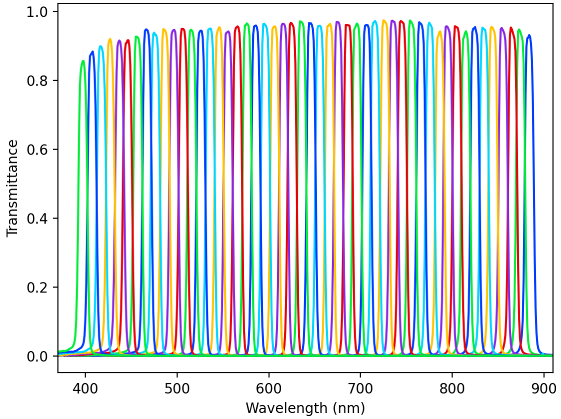
- We propose to introduce the human visibility function and design the optimal illumination spectrum under the visibility constraint.
  - Initialize the Illumination Spectrum via LED basis.
  - Incorporate human vision system to dynamically scale the illumination spectrum according to the threshold.
  - Simulate the imaging process and noise effect.
  - Optimize an image enhancement network.

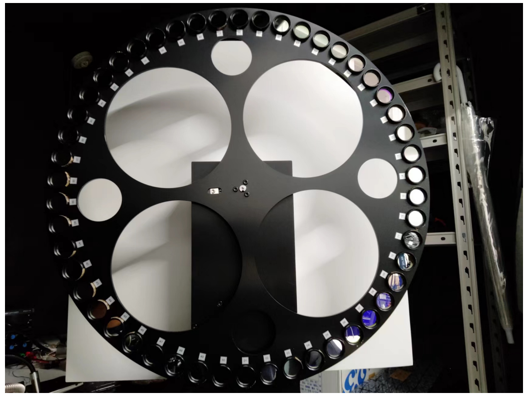


Dataset

- An Extended Hyperspectral Dataset
  - we contribute a new hyperspectral image dataset to supplement existing HSI datasets in terms of quality and quantity.
  - Hyperspectral images are taken using 50 band-pass filters.
  - The wavelength covers from 400 nm to 890 nm with 10 nm intervals. There are 74 scenes in the dataset, with a resolution of 1936 × 1096.

Datasets	ICVL	TokyoTech	IDH	Ours
Resolution	1392×1300	512×512	256×256	1936×1096
Scenes	201	16	112	74
Range	400-1000	420-1000	650-1000	400-890
Interval	1.25	10	10	10





Experiments

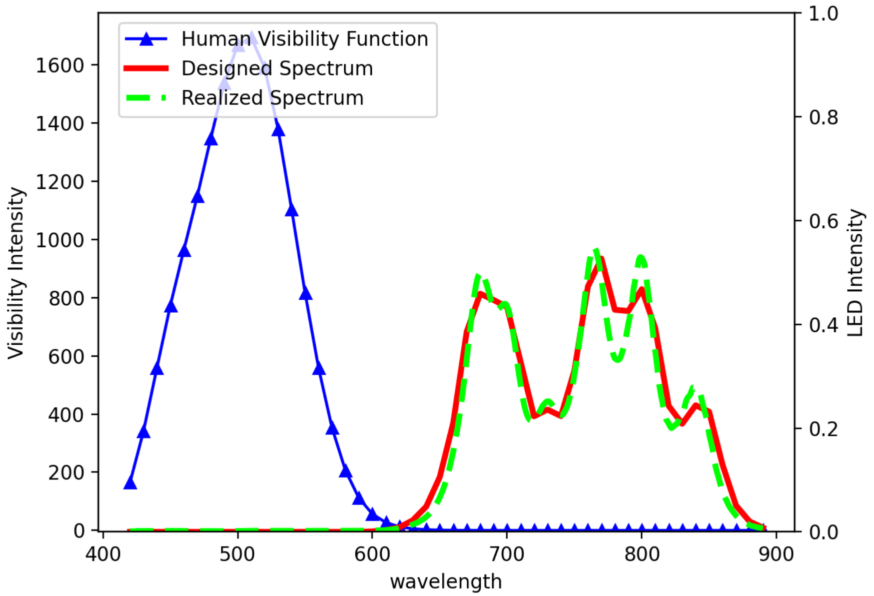
- Significant Improvement compared to NIR2RGB
  - Instead of empirically picking up the NIR range, we find the theoretically optimal curve under the visibility constraints.
  - As a result, we significantly robustify the task and achieve superior results on two datasets.

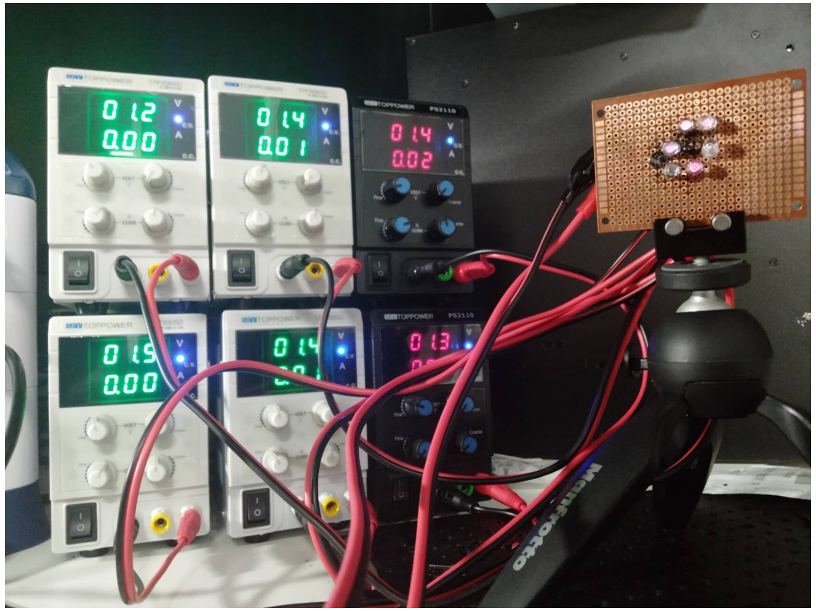
OptNIR | Ours-VIS-850nm | Ours-VIS-660nm | Ours-Full | Ground Truth

Datasets	Methods	SSIM	PSNR	LPIPS
Ours	OptNIR	0.7688	22.67	0.1590
	Ours-850	0.8305	24.07	0.1276
	Ours-660	0.8316	23.72	0.1232
	Ours-Full	**0.8383**	**24.12**	**0.1129**
Tokyo Tech	OptNIR	0.7191	19.65	0.1841
	Ours-850	0.7902	21.78	**0.1365**
	Ours-660	0.7628	21.45	0.1383
	Ours-Full	**0.7938**	**22.08**	0.1378

Experiments

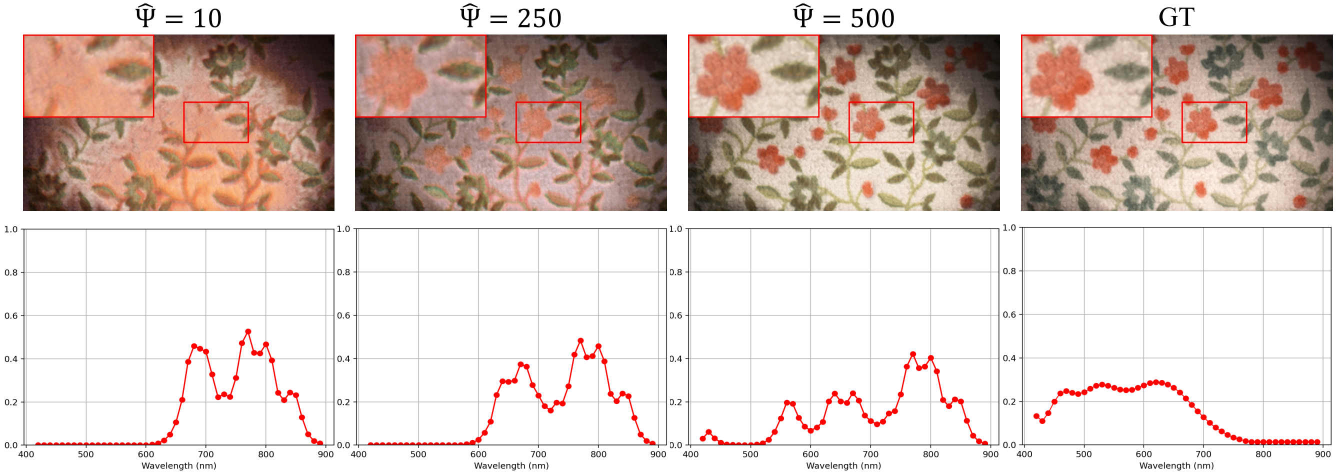
- Designed Optimal Illumination spectrum and the corresponding realization in the physic space





Experiments

- Impact of Visibility Threshold
  - As the value of threshold grows, the restoration results become better since more VIS information is covered.
  - We can trade visibility friendliness for restoration performance by setting different thresholds, making our model applicable to a wide range of application scenarios.



Datasets	Thres.	SSIM	PSNR	LPIPS
Ours	10	0.8383	24.12	0.1129
	250	<u>0.8779</u>	<u>25.64</u>	<u>0.0919</u>
	500	0.9326	29.07	0.0351
Tokyo Tech	10	0.7938	22.08	0.1378
	250	<u>0.8495</u>	<u>23.77</u>	<u>0.0920</u>
	500	**0.9375**	**31.85**	**0.0355**

Thanks!

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