Interpreting Intrinsic Image Decomposition using Concept Activations

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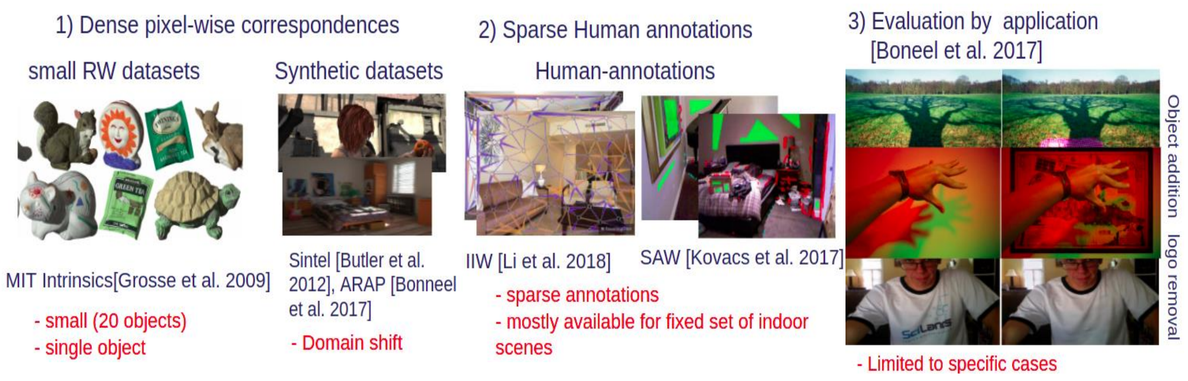
Abstract

- Evaluation of ill-posed problems like Intrinsic Image Decomposition (IID) is challenging.
- IID is under-constrained: more output parameters (R, S) than inputs (I).
- IID comparison with one specific decomposition in the ground-truth images used by current IID evaluation metrics like LMSE, MSE, DSSIM, WHDR, SAW AP%, etc., is inadequate.
- Measuring ***R-S disentanglement*** is a better way to evaluate.
- Inspired by ML interpretability methods, we propose **Concept Sensitivity Metrics (CSM)** that directly measure disentanglement using sensitivity to concepts of R-illumination invariance and S-albedo invariance.

Key Contributions

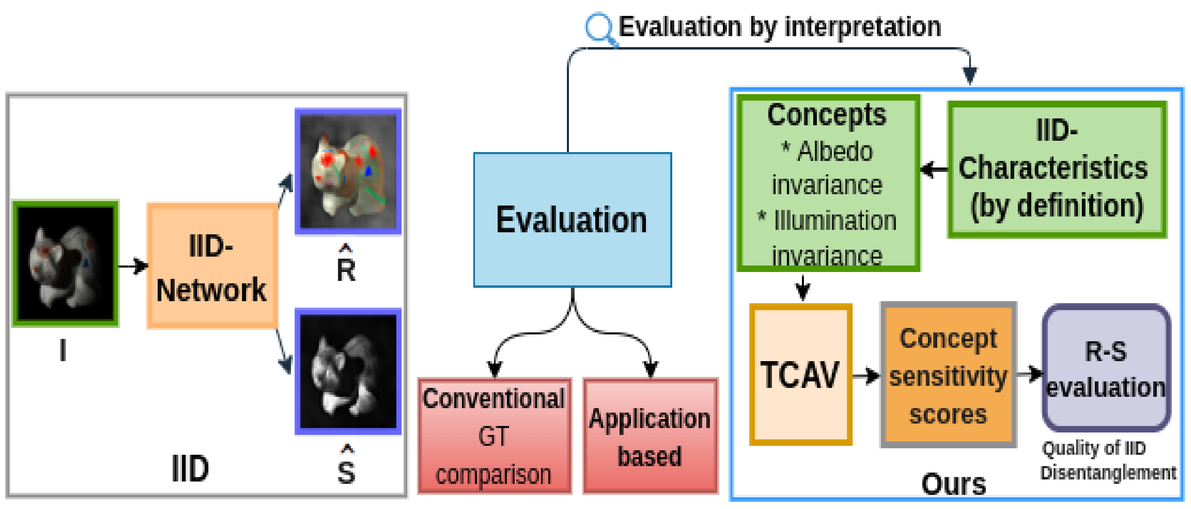
1. A **novel method for using ML interpretability** algorithms like TCAV to measure disentanglement.
2. A novel **IID performance evaluation metric**: **Concept Sensitivity Metric (CSM)** and benchmarked results on three state-of-the-art IID solutions.
3. **A new configurable dataset** of images and corresponding generation scripts with controlled illumination and albedo variation.

IID evaluation



Existing IID evaluation is limited as shown and doesnot measure disentanglement.

Evaluation by interpretation

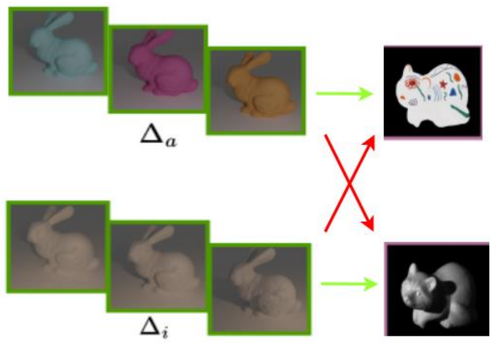


Concept Sensitivity

Ideal case of complete R-S **disentanglement**, R and S **sensitivity** for

- Δa: albedo change experiment
- Δi: illumination change experiment

$R_{\Delta a}$, $S_{\Delta i}$ = 1 and $R_{\Delta i}$, $S_{\Delta i}$ = 0.

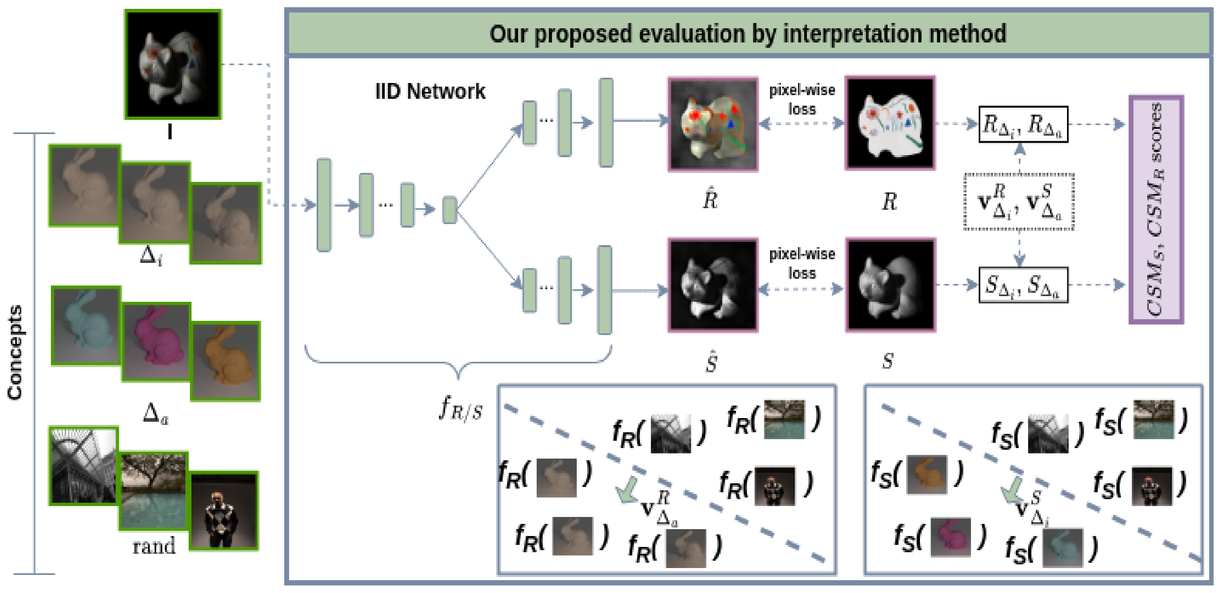


Concept Sensitivity Metric: CSM

- Quantitative measures proposed for **quality of R̂ vs. Ŝ disentanglement.**
- Two metrics:

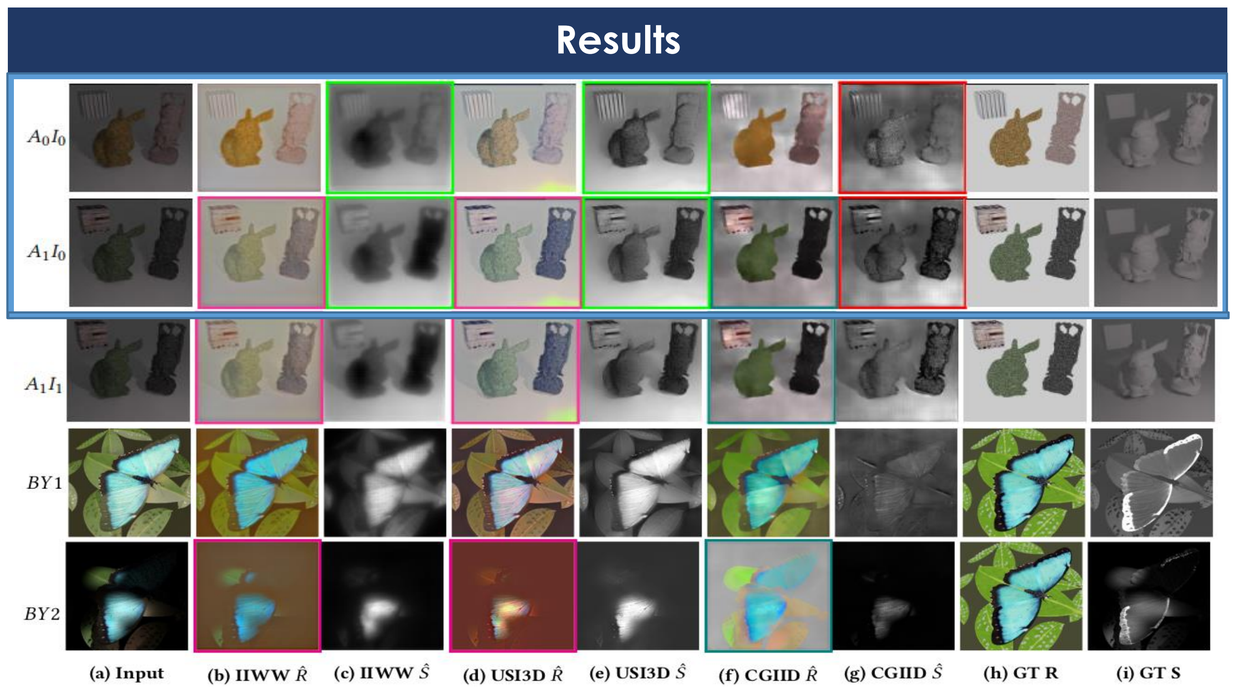
$$CSM_S = \frac{R_{\Delta_a}}{S_{\Delta_a}} \quad and \quad CSM_R = \frac{S_{\Delta_i}}{R_{\Delta_i}}.$$

Ŝ albedo invariance R̂ illumination invariance



Disentanglement Quality Assessment via our proposed CSM scores.

Results



Performance order over Synthetic Concept Sets

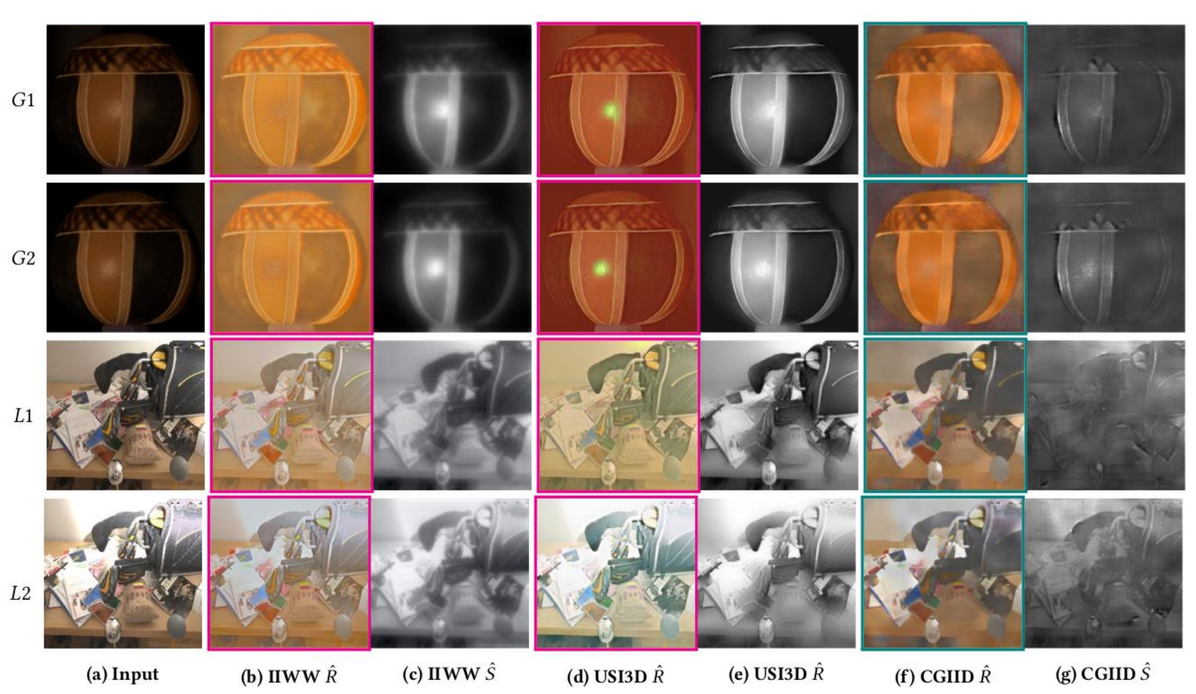
Albedo variation (A_0I_0 -> A_1I_0): USI3D > IIWW > CGIID
Illumination variation (A_1I_0 -> A_1I_0): CGIID > IIWW > USI3D

	Synthetic Concept Set		RW Concept Sets		
Model	**CSM_S**	**CSM_R**	**CSM_R**	**WHDR**	**SAW**
IIWW	1.524	0.878	0.991	20.3	91.87
USI3D	**2.139**	0.552	0.784	18.69	78.69
CGIID	0.909	**1.544**	**5.431**	**14.8**	**97.93**

CSM_S: USI3D > IIWW > CGIID, CSM_R: CGIID > IIWW > USI3D

Img	Model	R:MSE, LMSE, D-SSIM, LPIPS	S: MSE, LMSE, D-SSIM, LPIPS
A_0I_0	IIWW	0.025, 0.006, 0.254, 0.336	0.021, 0.004, **0.365,** 0.429
	USI3D	**0.013,** 0.006, **0.188, 0.185**	0.058, 0.006, 0.431, **0.396**
	CGIID	0.021, 0.006, 0.280, 0.364	**0.020, 0.003**, 0.421, 0.396
A_1I_0	IIWW	0.035, 0.011, 0.261,0.362	0.041, 0.011, **0.456,** 0.439
	USI3D	**0.014,** 0.006, **0.162, 0.153**	0.070, **0.010,** 0.495, **0.406**
	CGIID	0.062, 0.006, 0.327, 0.388	**0.041,** 0.014, 0.559, 0.443

Exemplar image comparison: Metrics fail to capture disentanglement quality.



Real world concept set results: Our method is **consistent** in both real world and synthetic domains while Other metrics have a domain shift.

Project Page: https://avani17101.github.io/Concept-Sensitivity-Metric/