LuminAIRe: Illumination-Aware Conditional Image Repainting for Lighting-Realistic Generation

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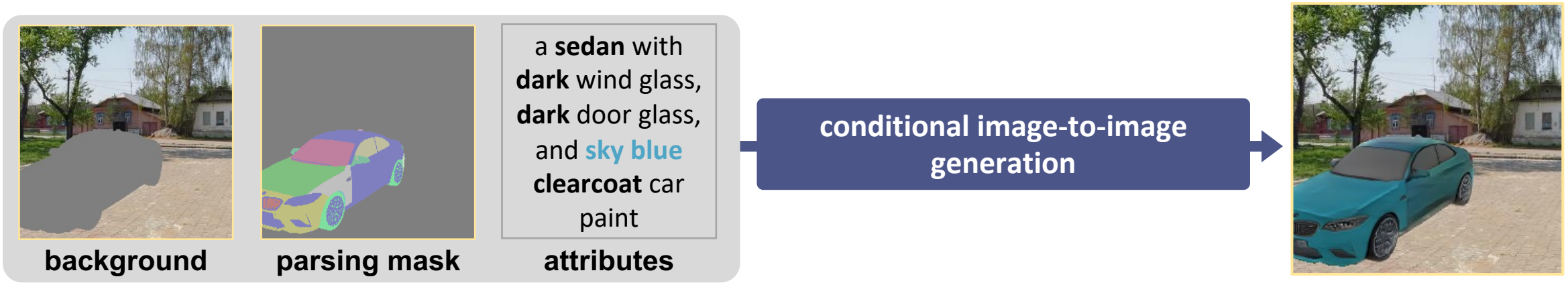
Problem

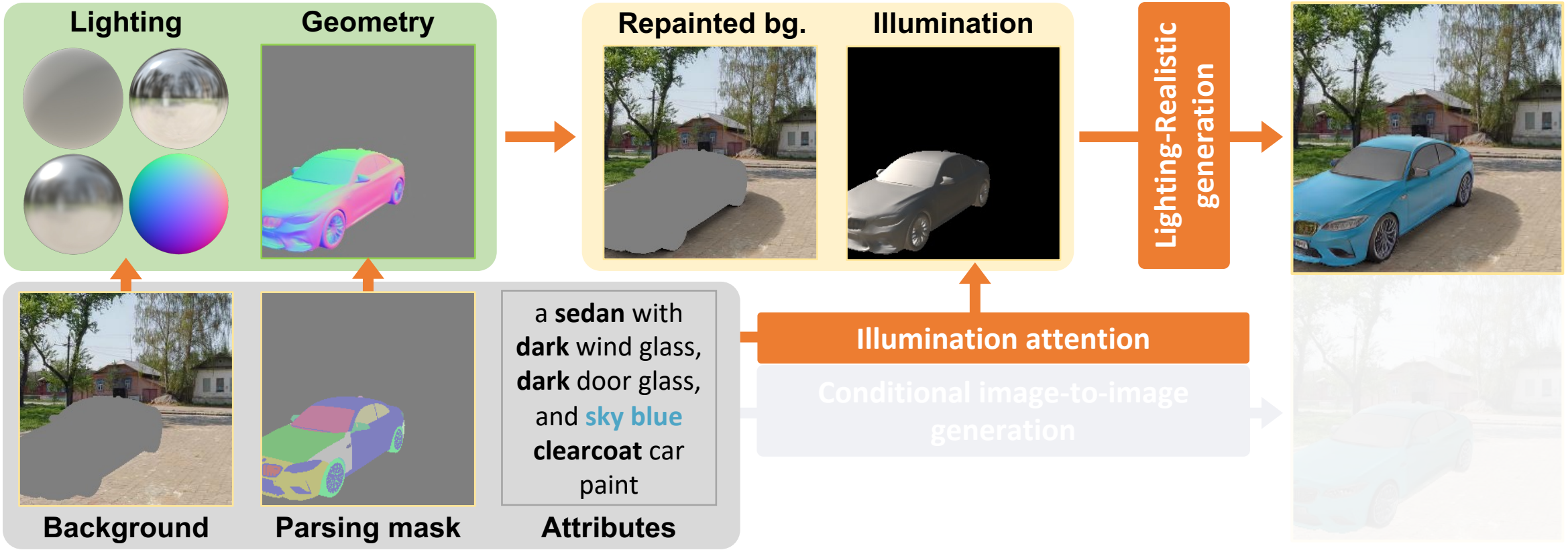
- Conditional image repainting (CIR) for image editing
  - generate foreground region according to user-given conditions
  - background, semantic mask, color, texture …



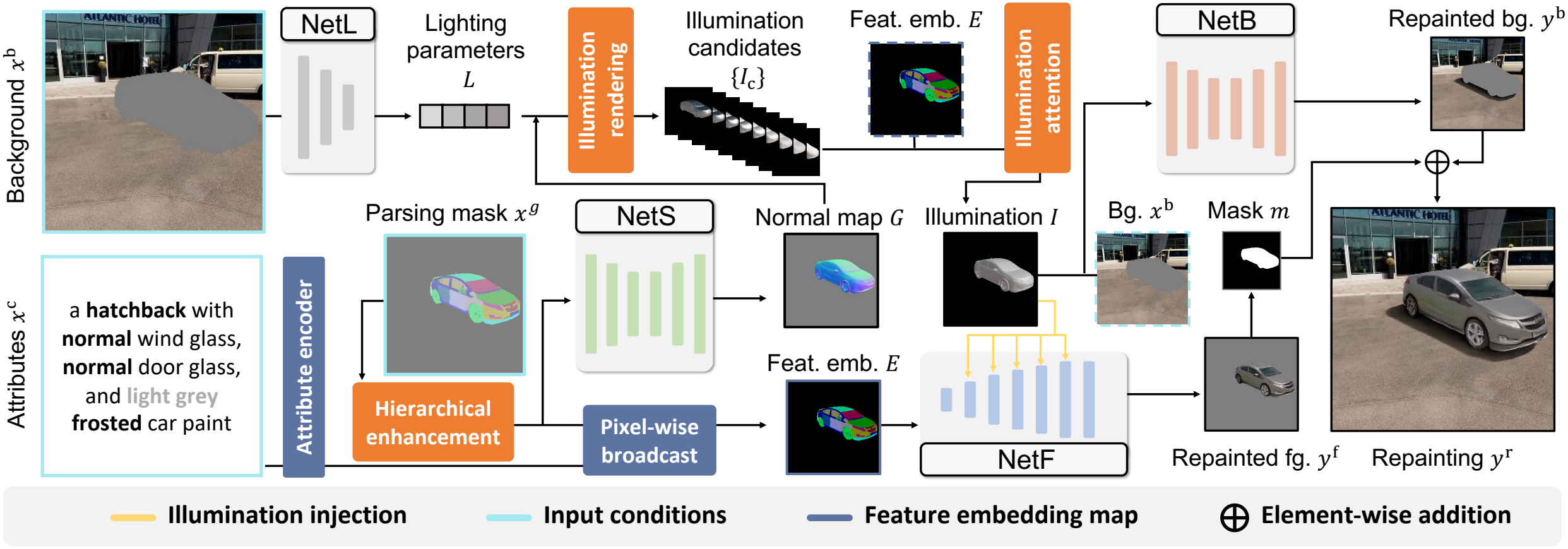
Mismatched lighting effects bring unrealistic and unharmonized perception

Problem

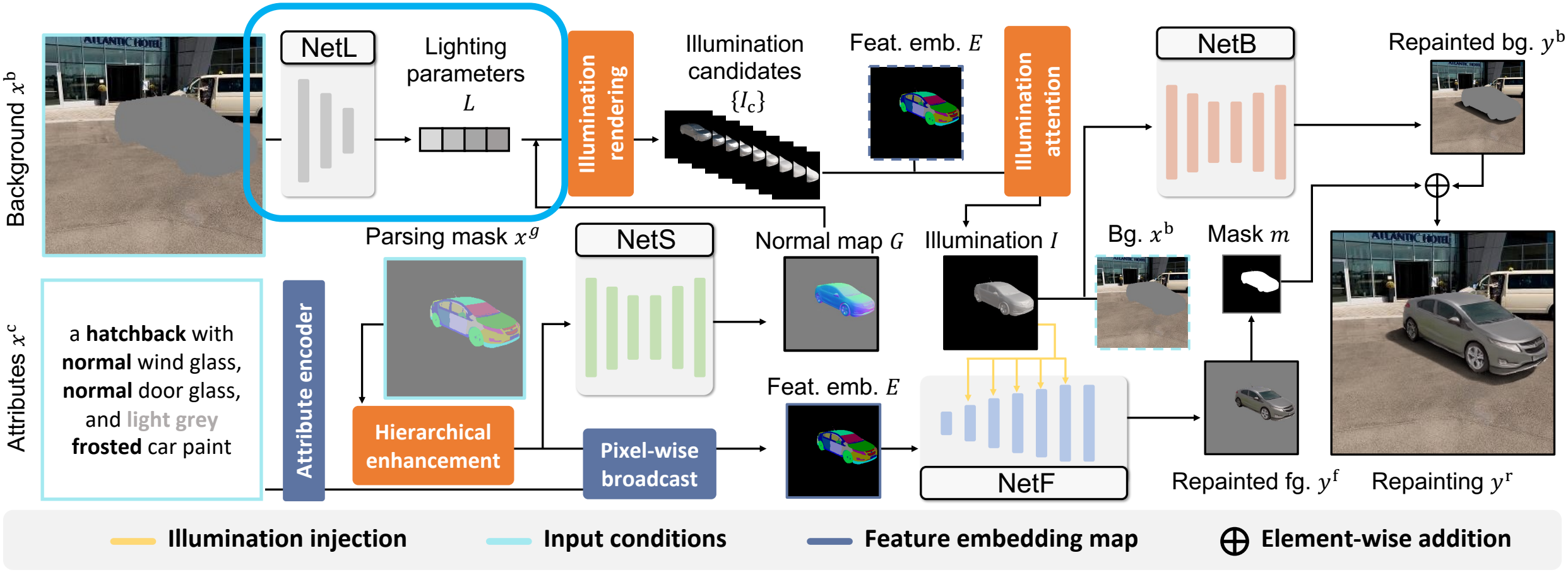
- I**llu**mination-**a**ware conditional **i**mage **re**painting (**LuminAIRe**)
  - user-given conditions contain **lighting** and **geometry** clues



Pipeline

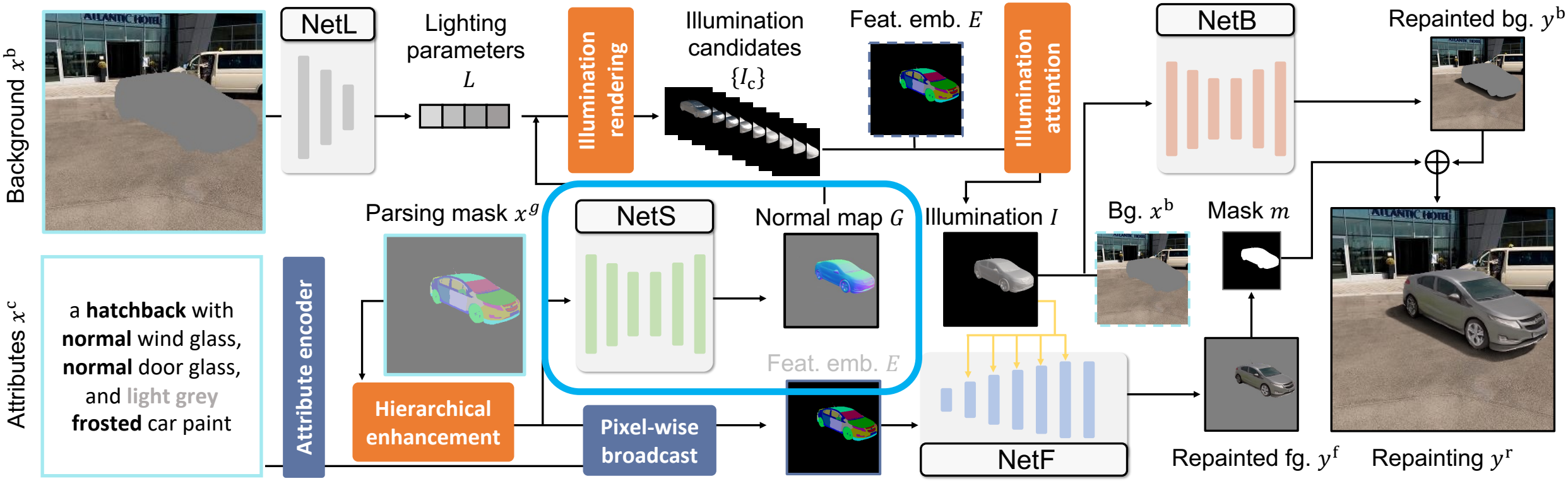

Background x^b
NetL
Lighting parameters L
Illumination rendering
Illumination candidates $\{I_c\}$
Feat. emb. E
Illumination attention
NetB
Repainted bg. y^b
Attributes x^c
a **hatchback** with **normal** wind glass, **normal** door glass, and light grey **frosted** car paint
Attribute encoder
Parsing mask x^g
Hierarchical enhancement
NetS
Normal map G
Illumination I
Bg. x^b
Mask m
Pixel-wise broadcast
Feat. emb. E
NetF
Repainted fg. y^f
Repainting y^r
Illumination injection
Input conditions
Feature embedding map
Element-wise addition

Pipeline



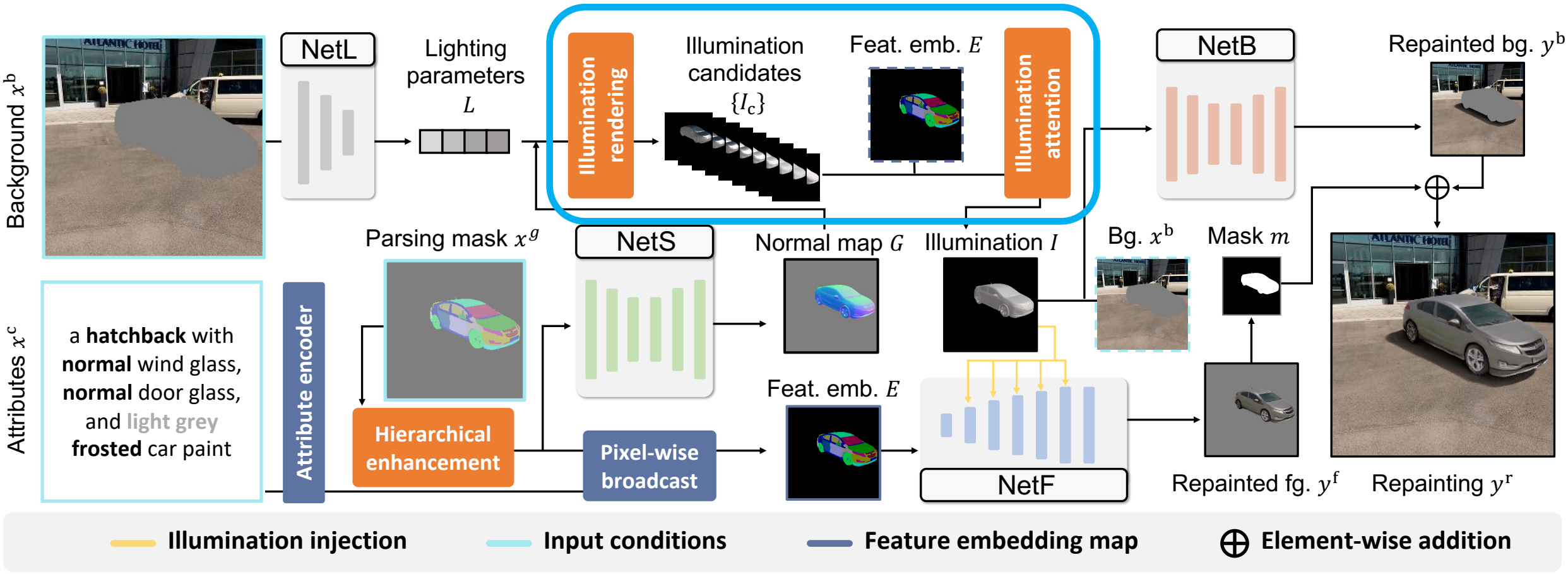
Estimate scene lighting information from the background image region

Pipeline



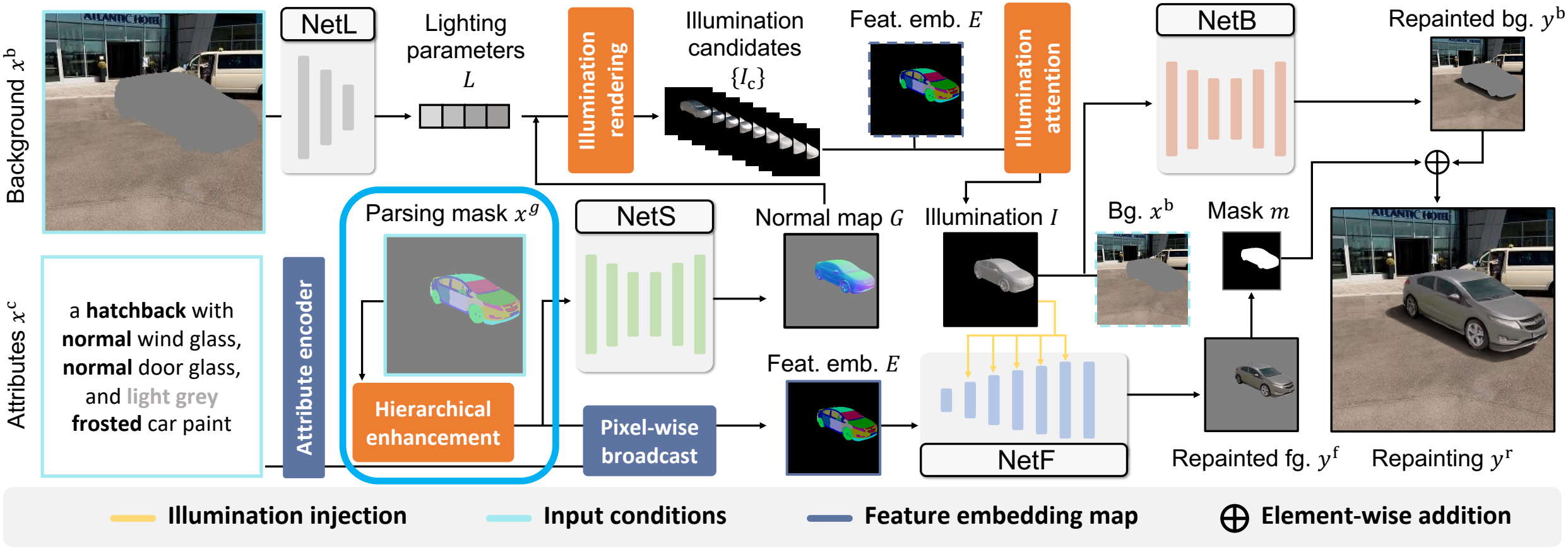
Estimate geometry information from the semantic parsing mask

Pipeline



Illumination images as the representation of lighting conditions for injection

Pipeline



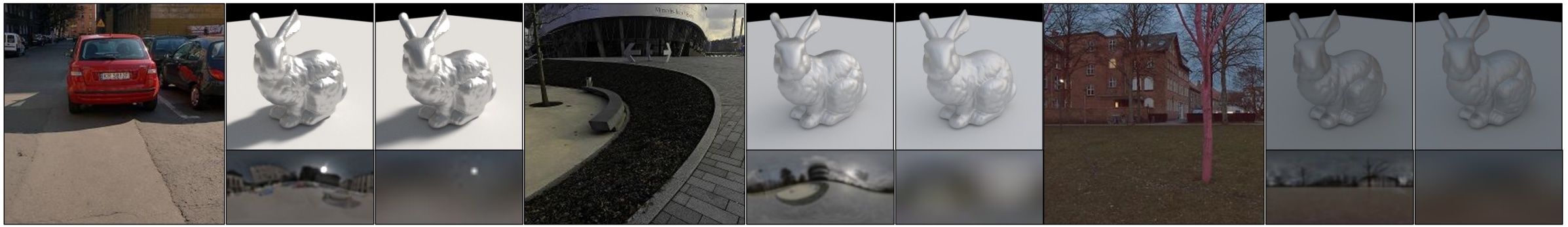
Hierarchical semantic labeling enhancement during training

Lighting representation

- For outdoor scenes, we assume spatially uniform global lighting
  - sky light: ambient low-frequency spherical harmonics (SH) lighting
  - sun light: directional lighting

$$L = \{z_{\text{vis}}, z_{\text{int}}, z_{\text{ang}}, c_{\text{sun}}, l_{\text{sun}}, \sigma_{\text{SH}}\}$$

$z_{\text{vis}} \in \{0,1\}$: sun visibility
z_{int}: sun intensity
z_{ang}: solid angle of sun
$c_{\text{sun}} \in \mathbb{R}^3$: normalized sun RGB
$l_{\text{sun}} \in \mathbb{R}^2$: sun direction
$\sigma_{\text{SH}} \in \mathbb{R}^{3\times 9}$: SH coefficients



Scene image | GT lighting | Our repr. | Scene image | GT lighting | Our repr. | Scene image | GT lighting | Our repr.

Lighting injection

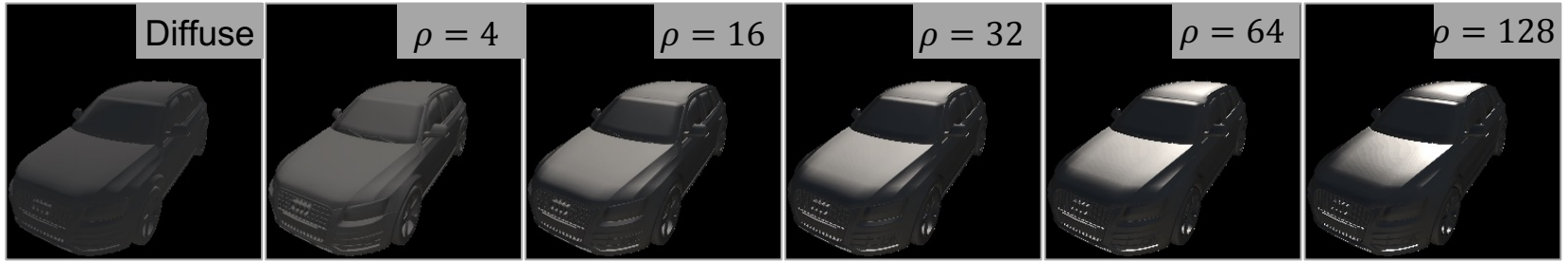
- Using the rendering equation to bridge **3D scene information** and **2D image conditions**

$$\underbrace{L_{\mathrm{o}}(\omega_{\mathrm{r}})}_{\text{appearance}} = \int_{\Omega_{\boldsymbol{n}}} \underbrace{L_{\mathrm{i}}(\omega_{\mathrm{i}})}_{\text{lighting}} \underbrace{f_{\mathrm{r}}(\omega_{\mathrm{i}}, \omega_{\mathrm{r}})}_{\text{reflectance}} \underbrace{(\boldsymbol{n} \cdot \omega_{\mathrm{i}})}_{\text{geometry}} \mathrm{d}\omega_{\mathrm{i}}$$

- Using Lambertian and Bling-Phong reflectance models with different roughness ρ to pre-compute illumination candidate images

$$f_{\mathrm{diff}}(\omega_{\mathrm{i}}, \omega_{\mathrm{r}}) = \frac{1}{\pi}, \qquad f_{\mathrm{spec}}(\omega_{\mathrm{i}}, \omega_{\mathrm{r}}) = \frac{(\rho + 4)(\boldsymbol{n} \cdot \boldsymbol{h})^{\rho}}{8\pi}, \qquad \boldsymbol{h} = \frac{\omega_{\mathrm{i}} + \omega_{\mathrm{r}}}{||\omega_{\mathrm{i}} + \omega_{\mathrm{r}}||}$$

Appearance variants



Illumination candidate images

Lighting injection

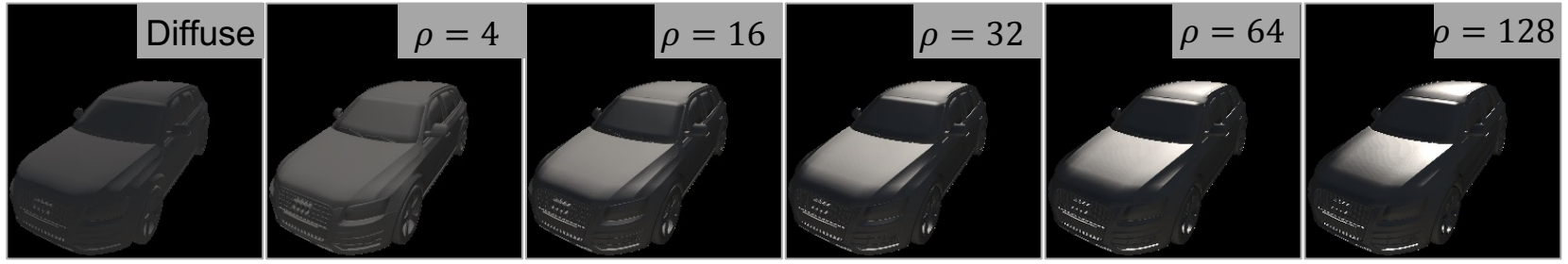
- Illumination candidate images $\{I_c\} = \{I_{\text{diff}}\} \cup \left\{I_{\text{spec}}^{\rho_i}\right\}_{i=1}^{M}$ can cover most lighting effects of appearance variants through linear combinations

- The coefficients are calculated from the illumination attention module A^{I}:

$$C_{\mathrm{I}} = \mathrm{A}^{\mathrm{I}}(E), \qquad I = \sum_{i=1}^{M+1} C_{\mathrm{I}}^{i} \odot I_{\mathrm{c}}^{i}$$

E: pixel-aligned feature embedding map of semantic labeling and attributes

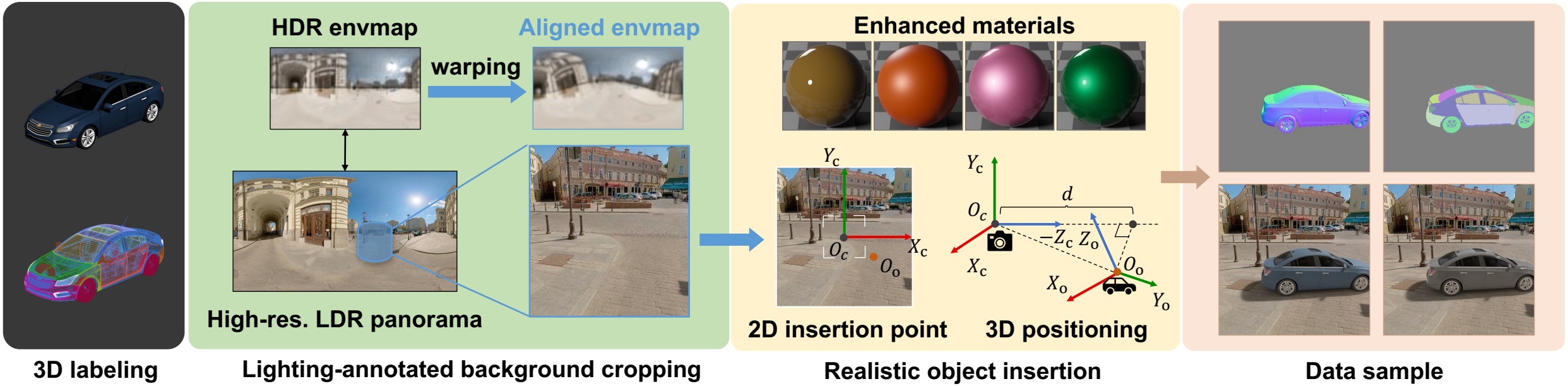
Appearance variants



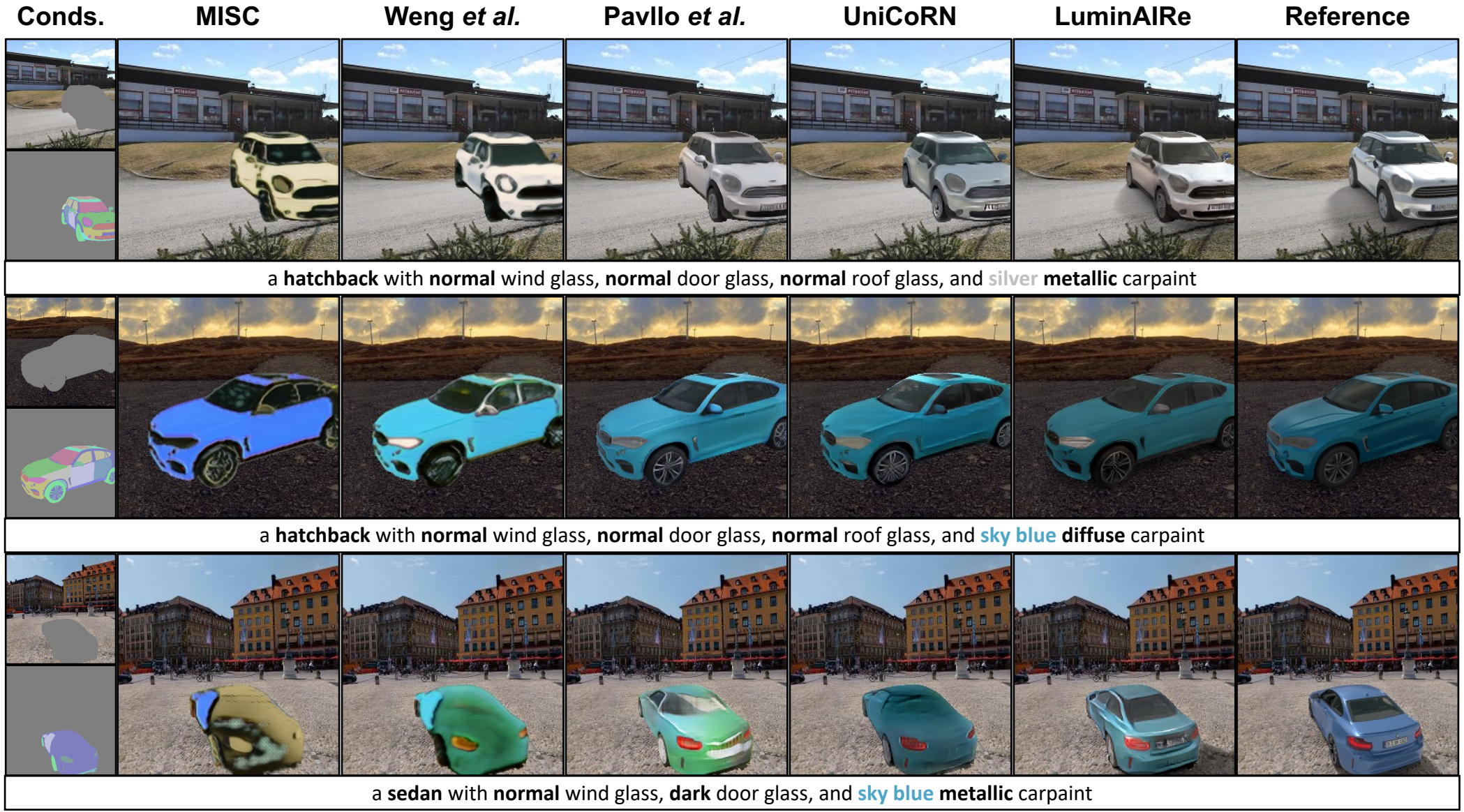
Illumination candidate images

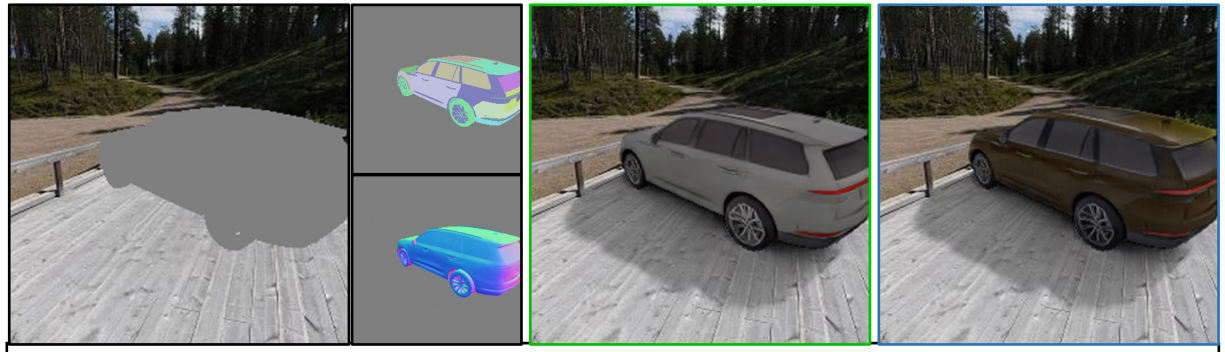
Synthetic dataset collection

- **Car-LuminAIRe** dataset



Results


Conds.
MISC
Weng et al.
Pavllo et al.
UniCoRN
LuminAIRe
Reference
a hatchback with normal wind glass, normal door glass, normal roof glass, and silver metallic carpaint
a hatchback with normal wind glass, normal door glass, normal roof glass, and sky blue diffuse carpaint
a sedan with normal wind glass, dark door glass, and sky blue metallic carpaint

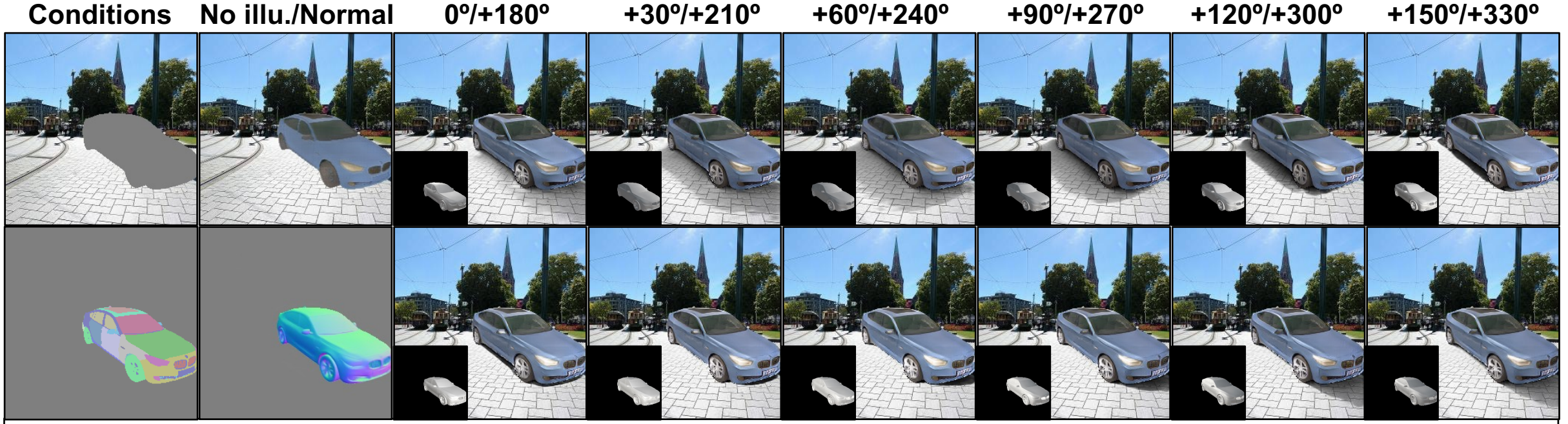


a **CUV** with **normal** wind glass, **dark** door glass, **dark** roof glass, and light grey **diffuse / brown clearcoat** car paint

Material editing test

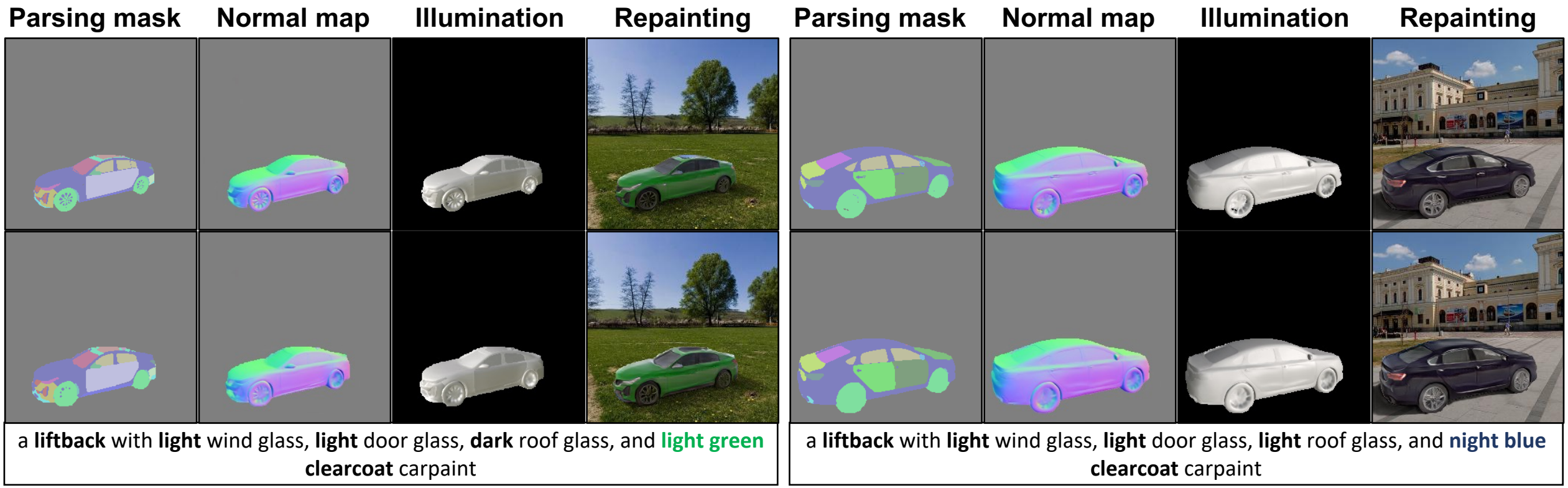
a **CUV** with **light** wind glass, **light** door glass, **light** roof glass, and grey **metallic** car paint

Lighting consistency test



a **liftback** with **normal** wind glass, **normal** door glass, **normal** roof glass, and blue grey **metallic** carpaint

Lighting rotation test



Parsing mask disturbing test

Summary

- Novel task of illumination-aware CIR (**LuminAIRe**)
- Pipeline for lighting information injection in the repaintings
- Synthetic dataset collection for LuminAIRe
- Validation of the effectiveness of our proposed method

See you at the poster session!

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