HDR Light Probes for Mixed Reality environments

Master's Thesis

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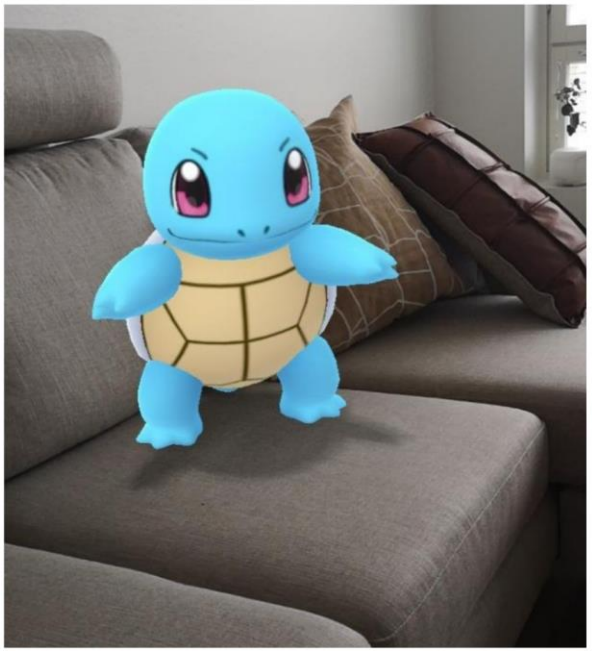
Mixed Reality (MR)

(a) VR application: Half-Life: Alyx [102]

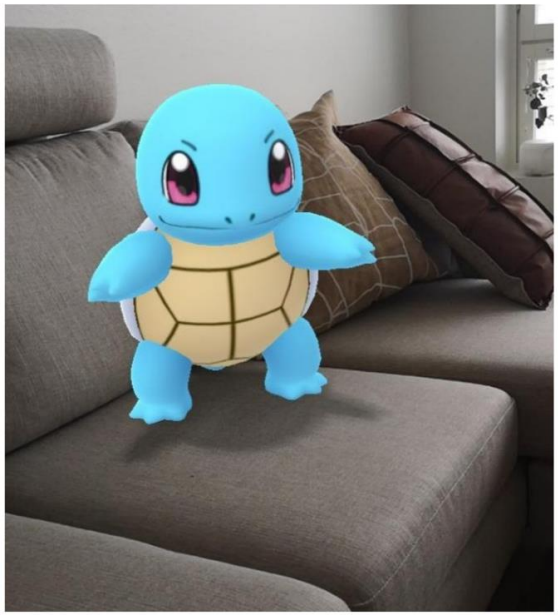


(b) AR application: Pokemon GO [64]

- Mixture of VR and real world
- Entertainment, information overlay, education

Valve; Niantic

Conventional systems



- Low quality and visual coherence
- Basic shadow, no light adaptation

Ikea Place, Niantic

HDR solution

- Consistent with scene
- Accurate shadows, realistic lighting – Light probes

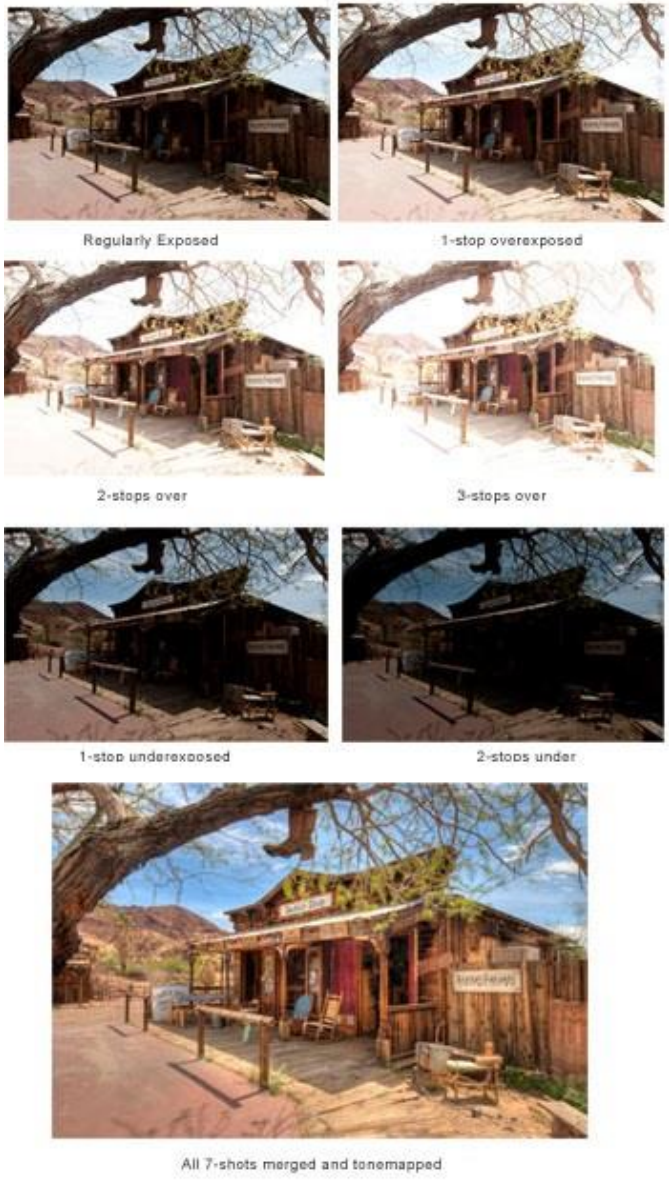
Image Based Lighting (IBL)

- Images serve as light source, cubemaps
- HDR Images usually mandatory
- Goal: Realistic lighting experience

Reinhard et al., 2010

High dynamic range (HDR)

- Greater bit depth, range of luminance, color volume + bigger file size
- Exposure series
- Trending technology
- Currently problematic displaying



Szeliski et al., 2010; dpreview.com

Tonemapping

- Reduce image gradients to fit the available dynamic range
- Goal: reproduction of human eye experience

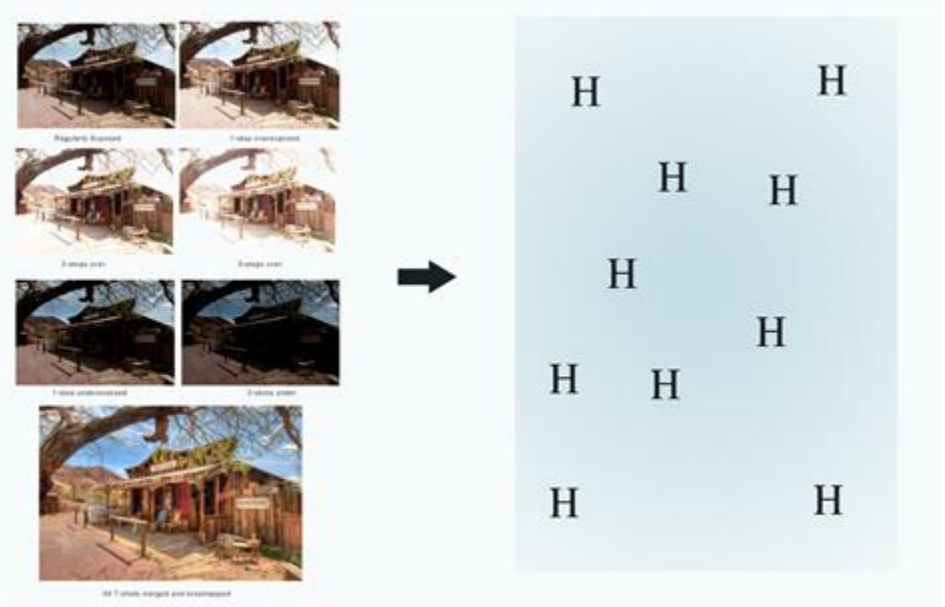
Reinhard et al., 2005

Capturing Data

Samsung Gear 360°

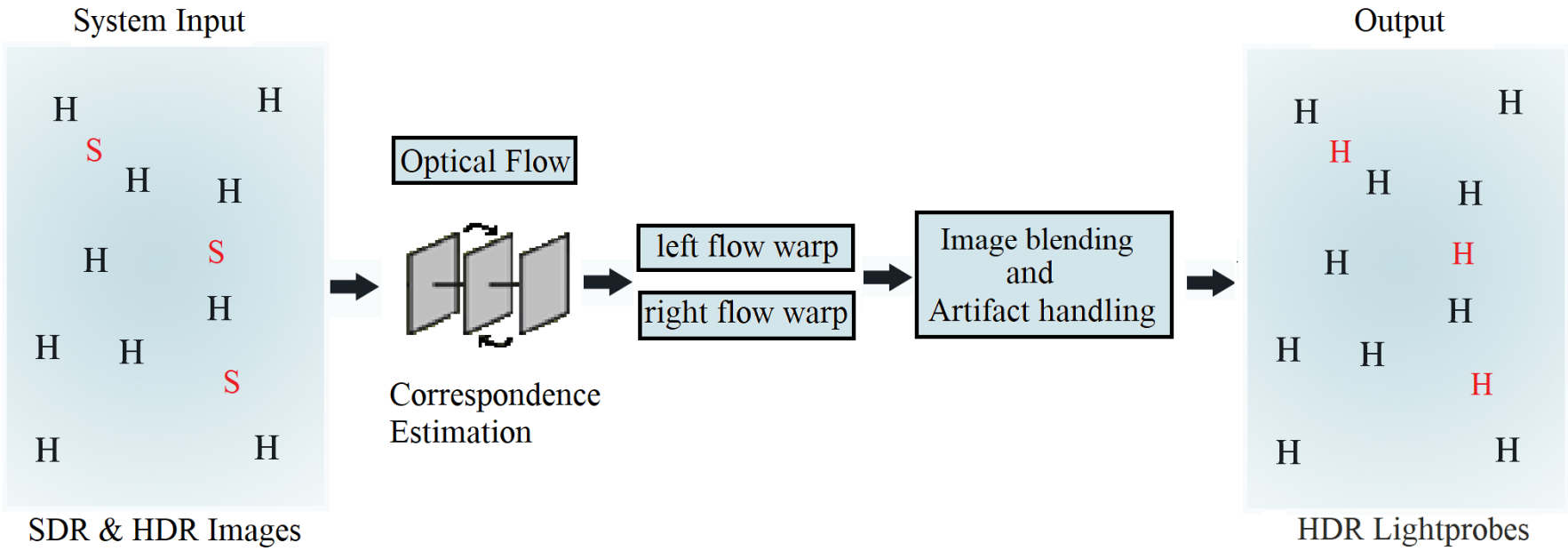
Samsung Galaxy S9

System structure

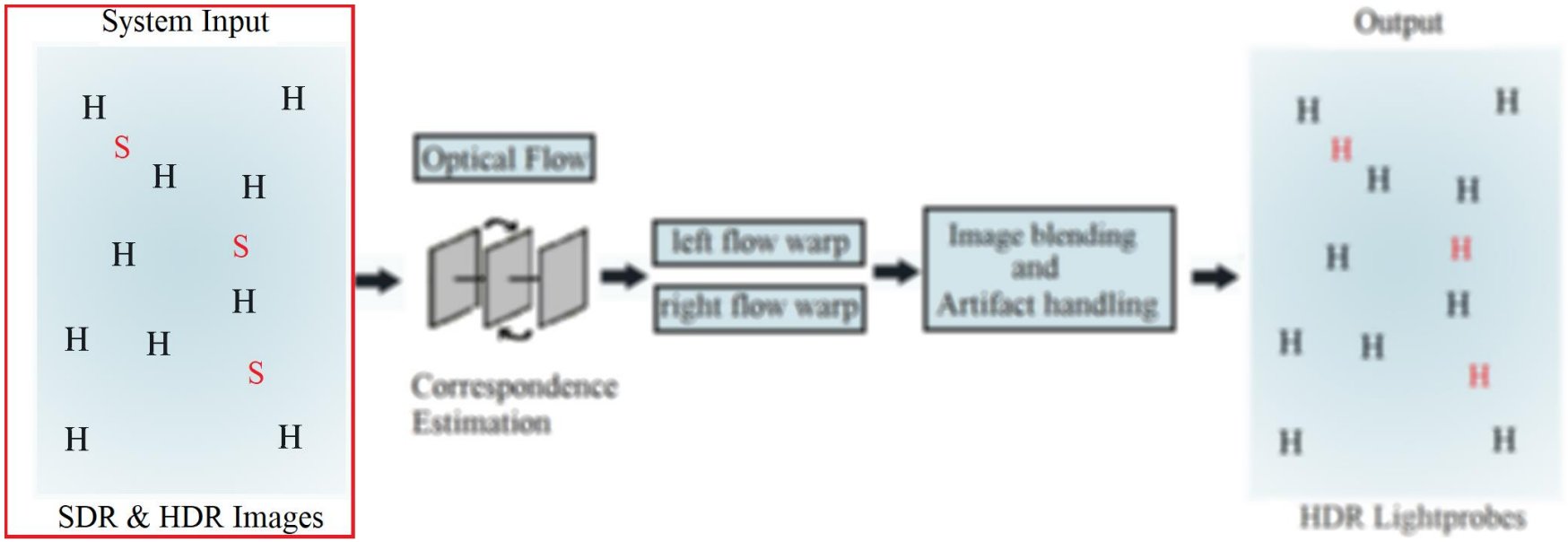


Light probe interpolation

System structure – Part I

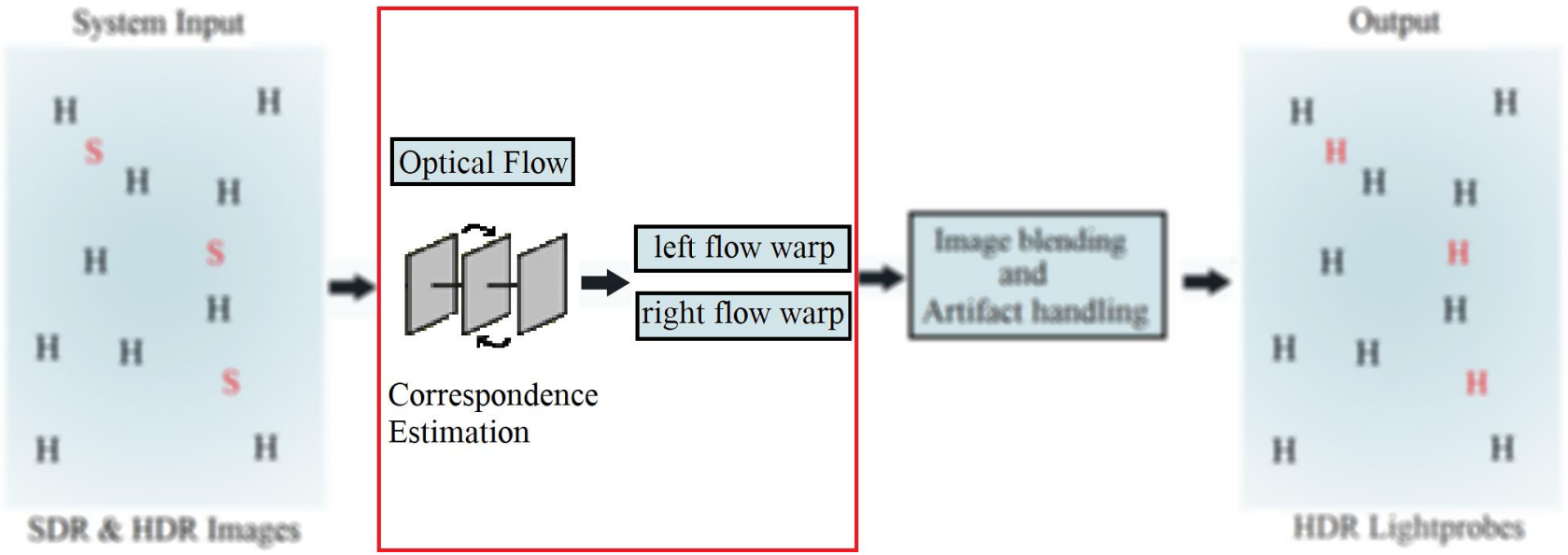


System structure – Part I



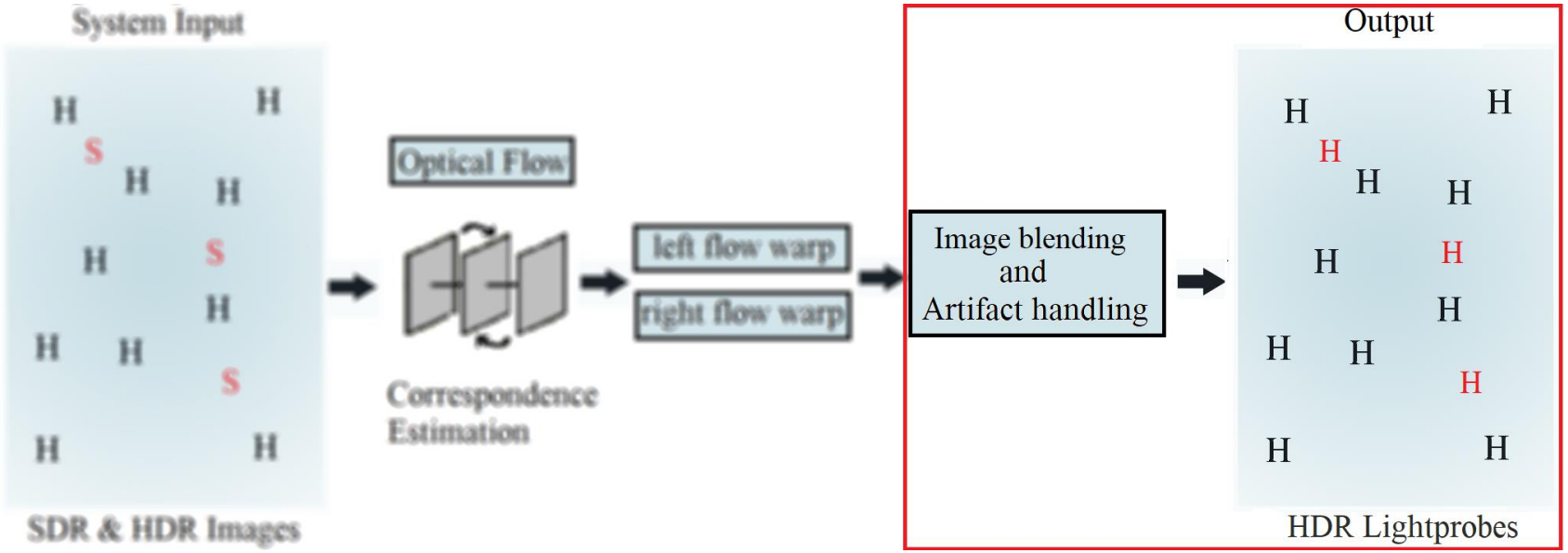
- SDR frames
- Sparse HDR frames

System structure – Part I



- Optical flow of SDR frames applied to adjacent HDRs
- Two frames per SDR position

System structure – Part I



- Blending warped frames together
- Multi-label Graph-cut optimizaton
- Artifact handling like α-ß swap

SDR vs. HDR IBL

(a) SDR IBL with SDR background

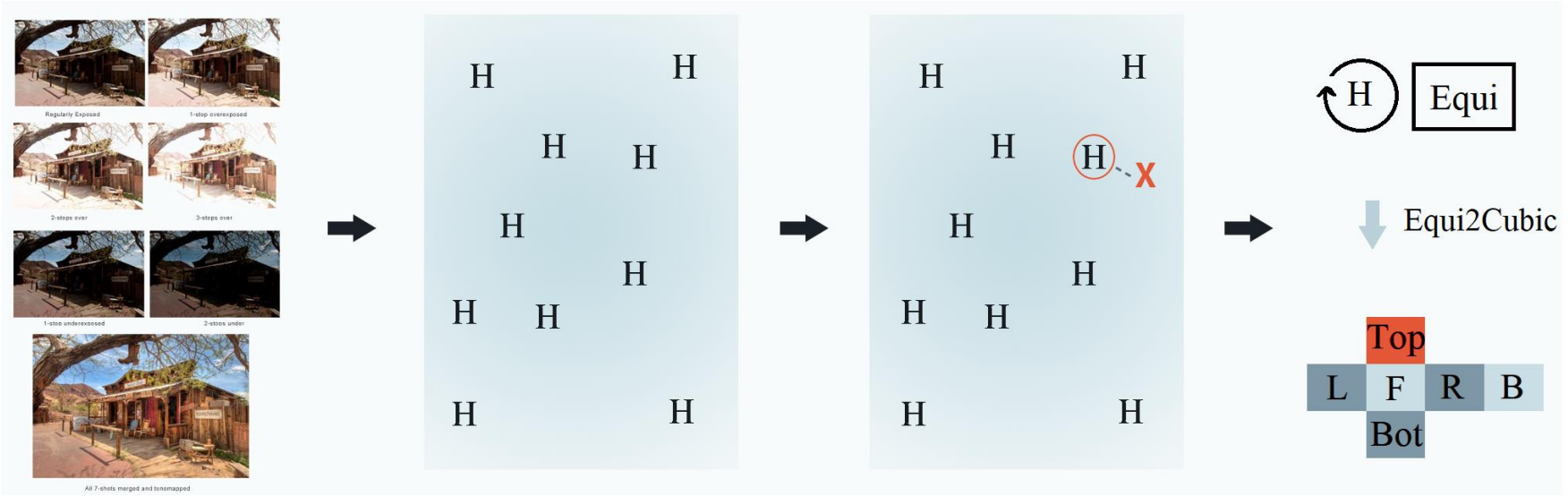
(b) HDR IBL with SDR background

AR use-case

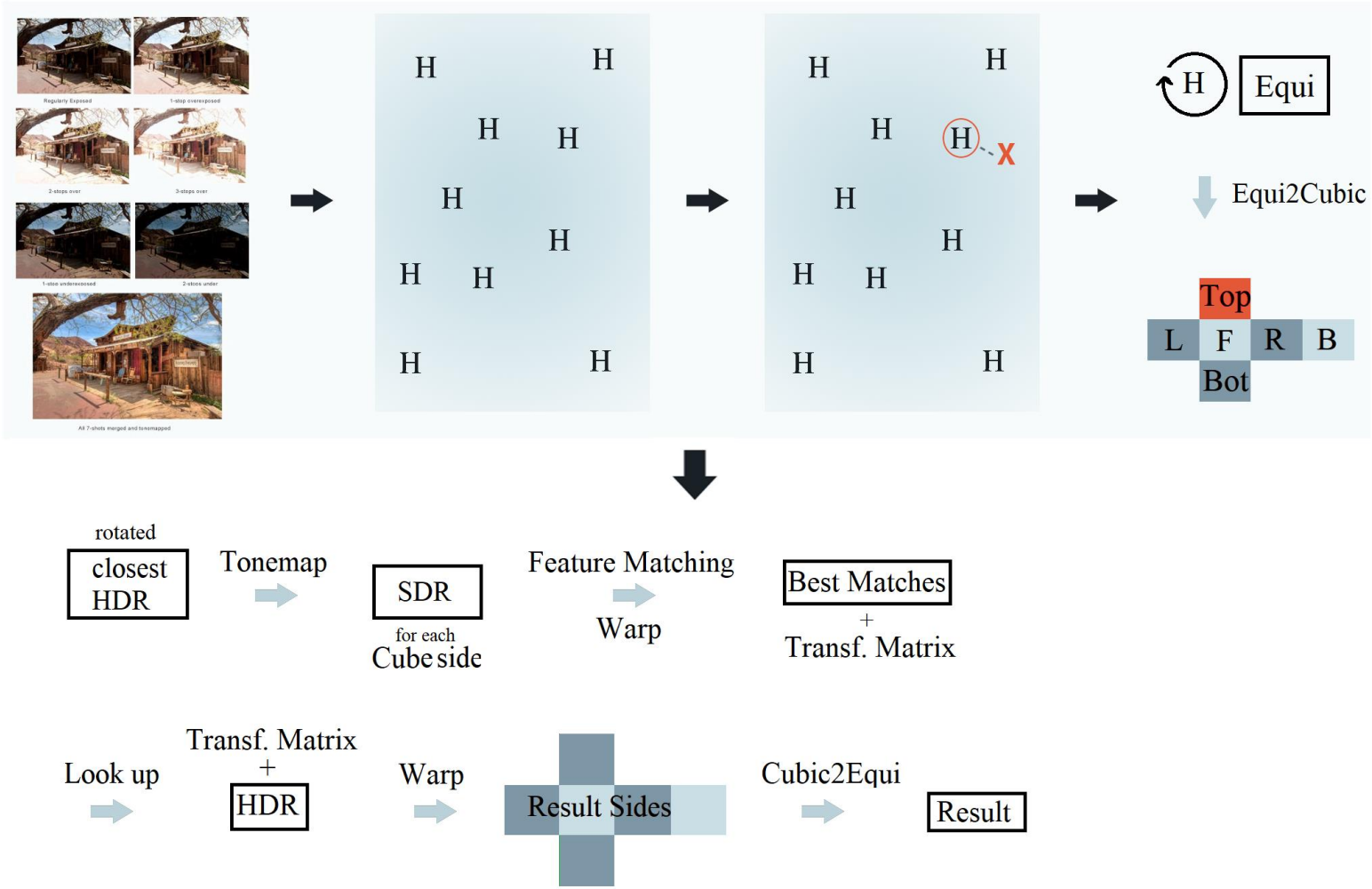
- Light probe interpolation: Not fast enough for realtime
- Interpolation (Optical Flow): 512x256 ~9 sec.

- Solution: Improved run time (near online) > Warping
- Simpler but quicker + artifacts

System structure – Part II

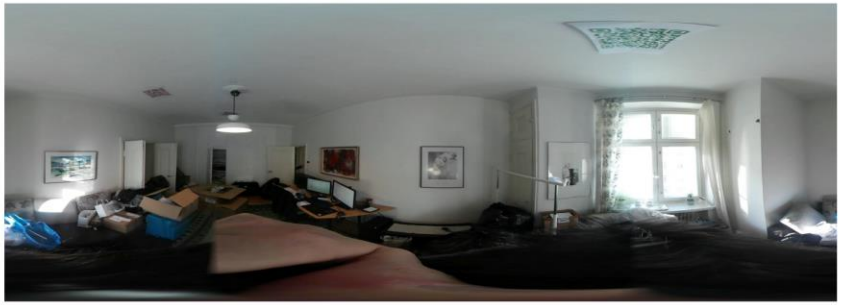


System structure – Part II



Scenes

(a) Kitchen-scene: Only artificial light



(b) Flat-scene: Natural- and artificial light

(c) Outdoor-scene: Only natural light

Qualitative results - Kitchen

(a) Mirror Shield: Highly reflective [32]

(b) Corset: Diffuse + specular details [45]

(c) Duck: Diffuse Object [45]

(d) Ikea chair Poäng: Real-life Object [13]

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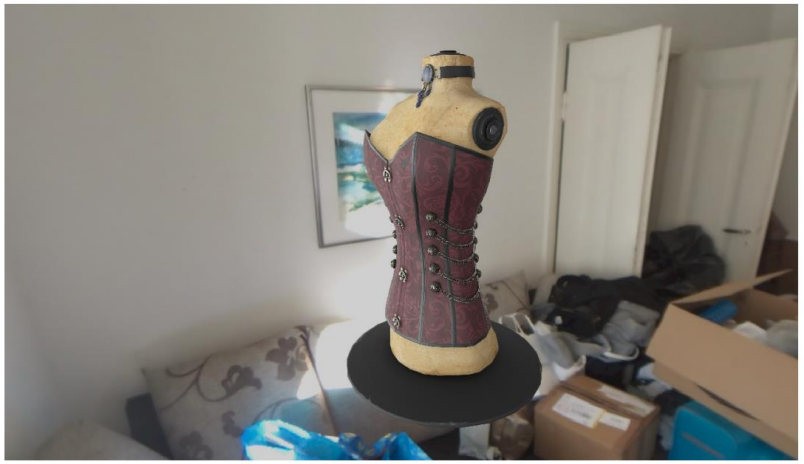
Qualitative results - Flat

(a) Mirror Shield: Highly reflective [32]



(b) Corset: Diffuse + specular details [45]

(c) Duck: Diffuse Object [45]

(d) Ikea chair Poäng: Real-life Object [13]

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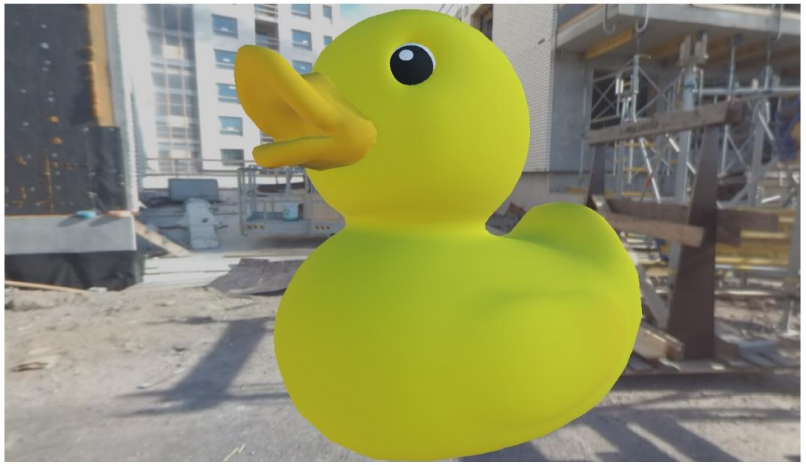
Qualitative results - Outdoor

(a) Mirror Shield: Highly reflective [32]

(b) Corset: Diffuse + specular details [45]



(c) Duck: Diffuse Object [45]

(d) Ikea chair Poäng: Real-life Object [13]

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Runtime

- Runtime of „interpolation“ system: ~9,0s
- Runtime of basic „warp“ system: ~2,1s
- Runtime of enhanced „warp“ system: ~0,19s
- Resolution and rotation dependent:
  4K: 14sec.
  Full HD: 4sec.

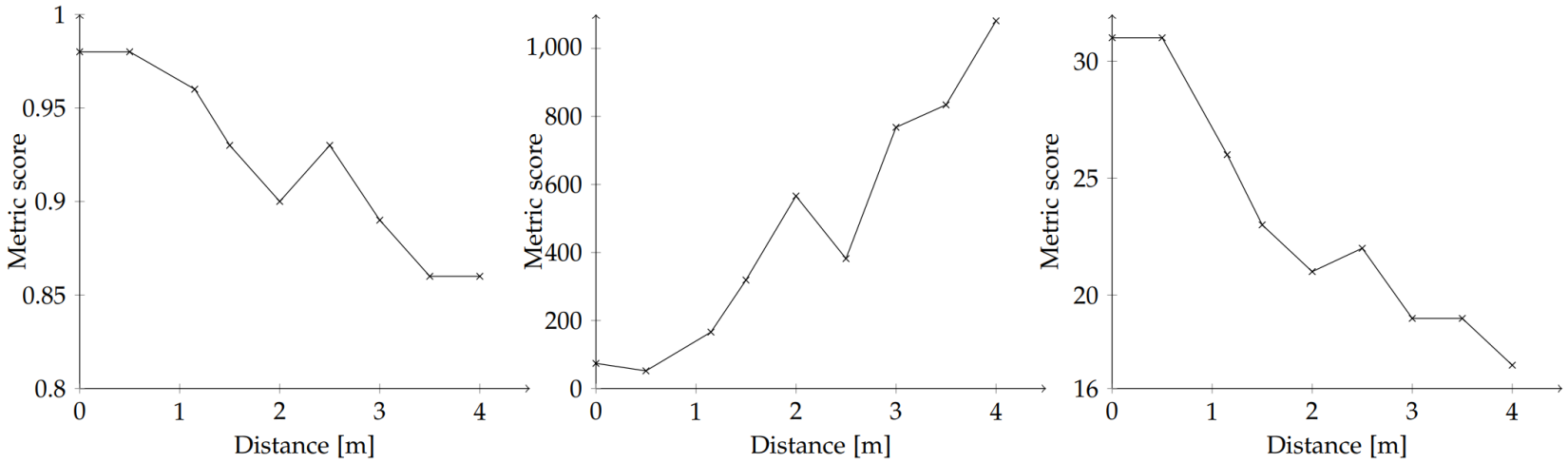
Evaluation

- Structural similarity (SSIM), Mean squared error (MSE), Peak signal to noise ratio (PSNR)
- 90-99% SSIM, 5-350 MSE, 22-44 PSNR
- Artifacts
- Results decline with distance

Wang et al., 2003+2004; Banterle et al., 2011

Evaluation

- Scores decline with distance



(a) SSIM (b) MSE (c) PSNR

Qualitative AR results - Video

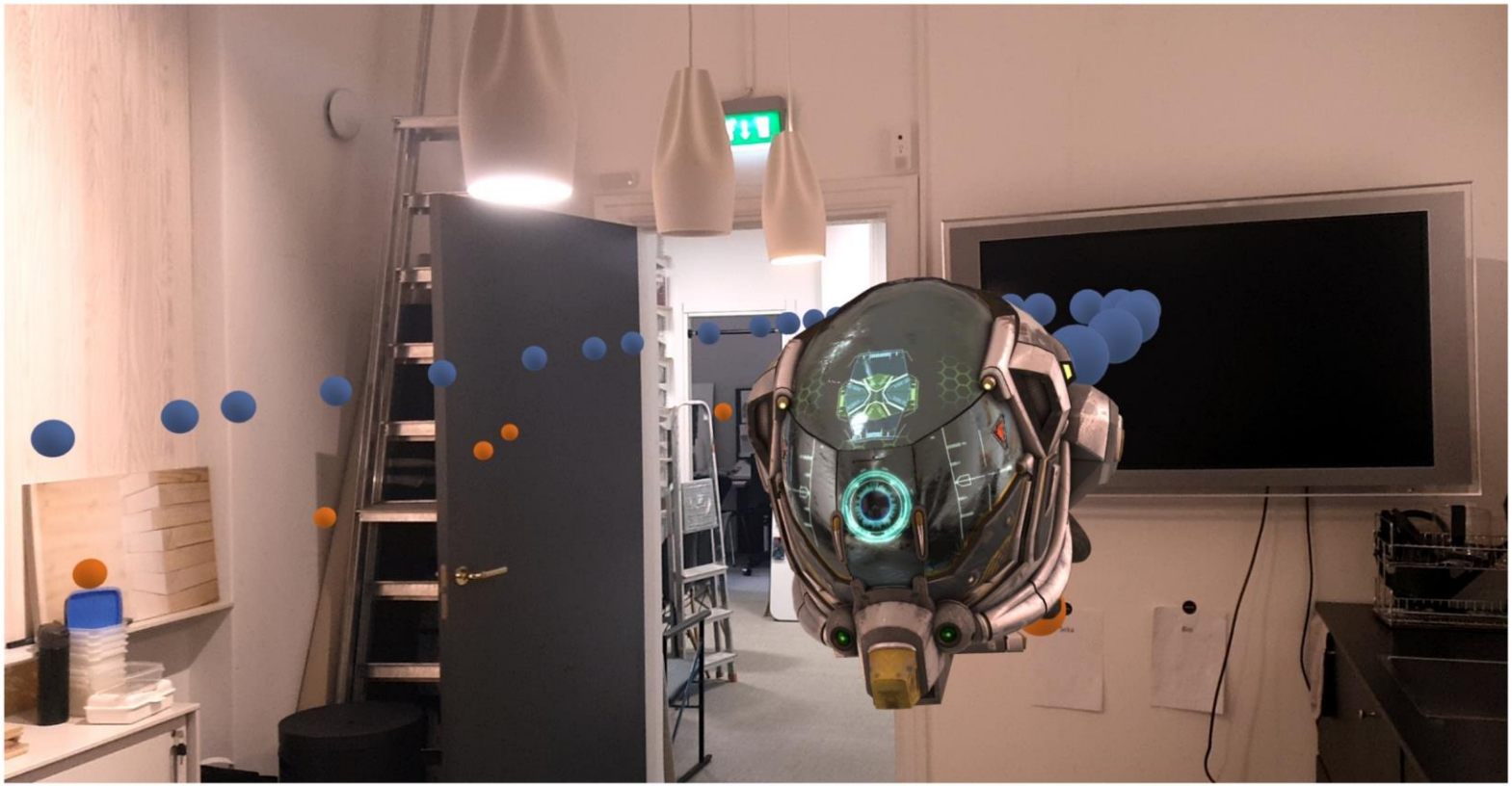


Figure 4.1: Screenshot from created Unity AR application

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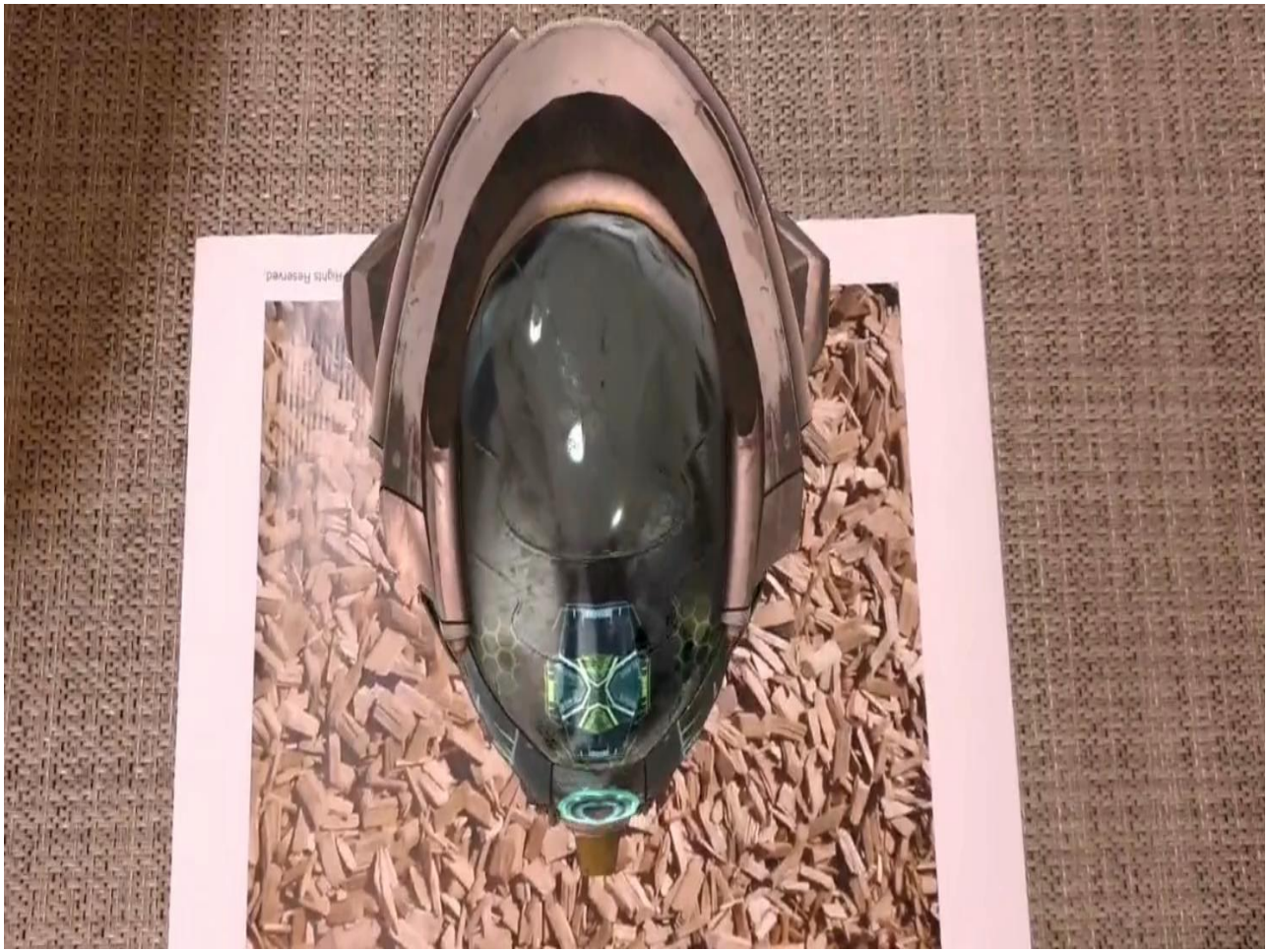
Qualitative AR results - Video



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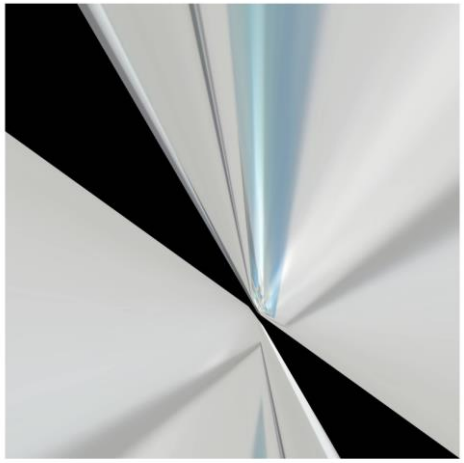
Limitations

- Lack of features; similar objects; non-optimal parameters
- Reflected in evaluation metrics



(a) Failed warping: strong distortions

(b) Warping errors: duplicate objects, distortions and holes

Conclusion and Future work

- Generally credible results + various fields of use:
  > Light probe interpolation (slow)
  > Matching and warping
- Scene + data dependent

- Quality of life features: GUI, System architecture…
- GPU Hardware accelation
- Further MR applications

Thank you for your attention.

Sources

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