Sticking Information in Plain Sight: Encoding and Detecting Hidden Stickers in the Real World

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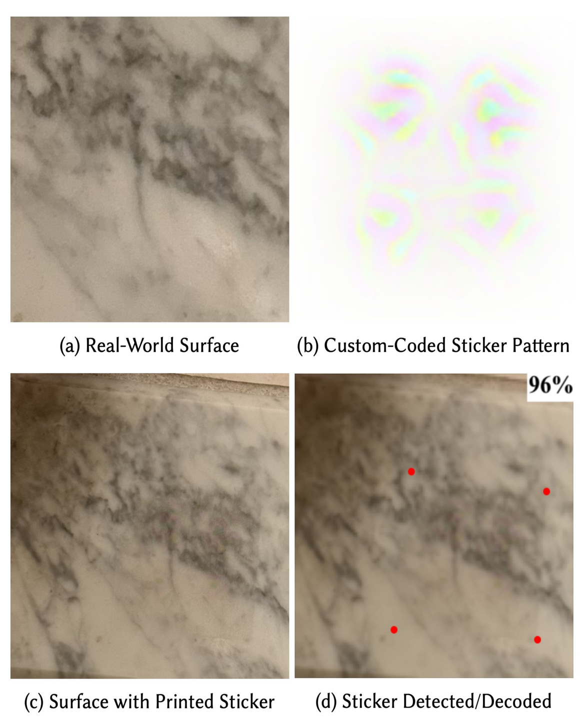
Motivation

- Being able to easily incorporate hidden data into the real world is advantageous in a number of scenarios that range from consumer-based interactions to industrial manufacturing.

Approach

- We optimize patterns, encoding 100 total bits, that are nearly **imperceptible** when **printed** on transparent sticker paper and applied to **real-world surfaces.** When photographed, encoded sections can be robustly localized and accurately decoded.
- Each pattern is generated specifically for a supplied surface location (*cover* image), resulting in a *container* image.
- Optimized to be resistant to **human error in sticker placement**, making it easy to deploy in the real world.



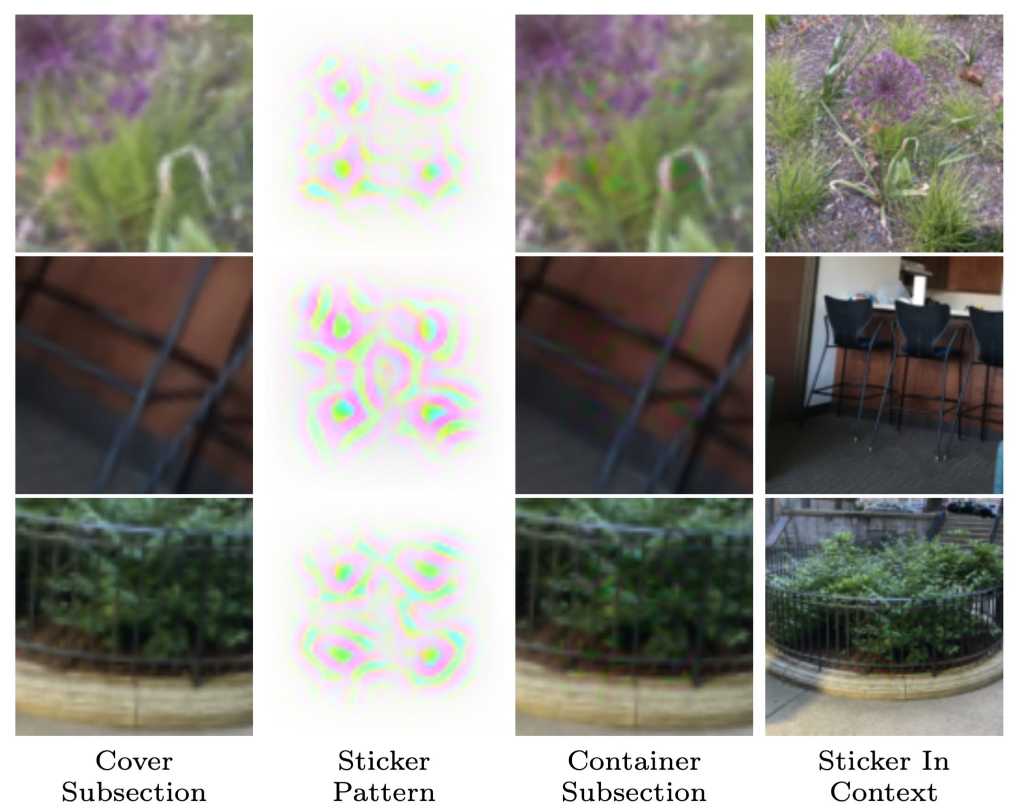
Methodology

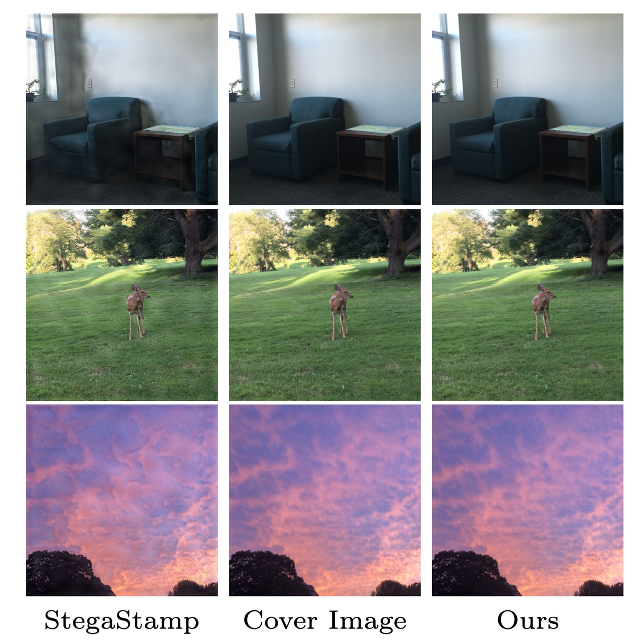
- Encoder: UNet [2].
- Decoder: Convolutions followed by linear layers.
- Localizer: A variant of HRNet [4].
- **Balance imperceptibility and robustness** by jointly optimizing the encoder, decoder and localizer.
- Simulate human placement error by introducing jitter between the cover subsection a pattern is optimized for, and the actual subsection where a sticker is placed.

Results

Simulation:

- Our method has average decoding accuracies of 99.14% for clean images and 89.16% with simulated noise, blur, color jitter, and perspective warp.
- A 0.0632 LPIPS score [5] demonstrates good imperceptibility.
- With perfect alignment, StegaStamp [3] achieves 2.40% higher decoding accuracy, but at the cost of greater perceptibility (0.0664 higher LPIPS).
- At 10 pixels of misalignment, StegaStamp achieves 17.32% **lower** decoding accuracy and 0.0999 higher LPIPS.

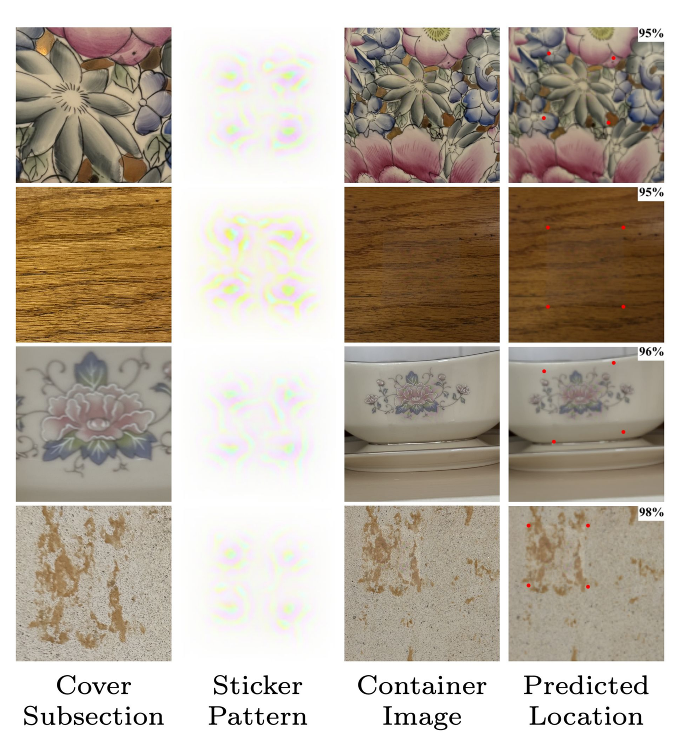


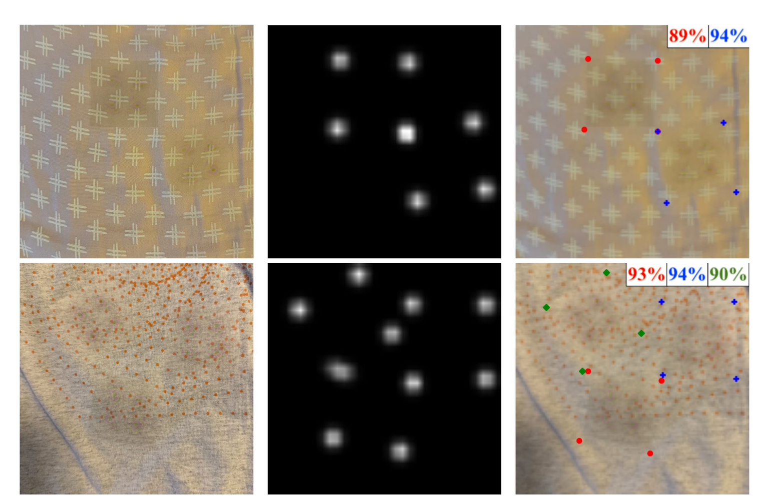


Method	Image Size	Encoding Size	PSNR ↑	SSIM ↑
Ours	400 × 400	400 × 400	**32.27**	**0.9792**
StegaStamp	400 × 400	400 × 400	28.60	0.8857
Ours	170 × 170	64 × 64	**40.62**	**0.9922**
Jia *et al.* [1]	256 × 256	96 × 96	32.95	0.9677

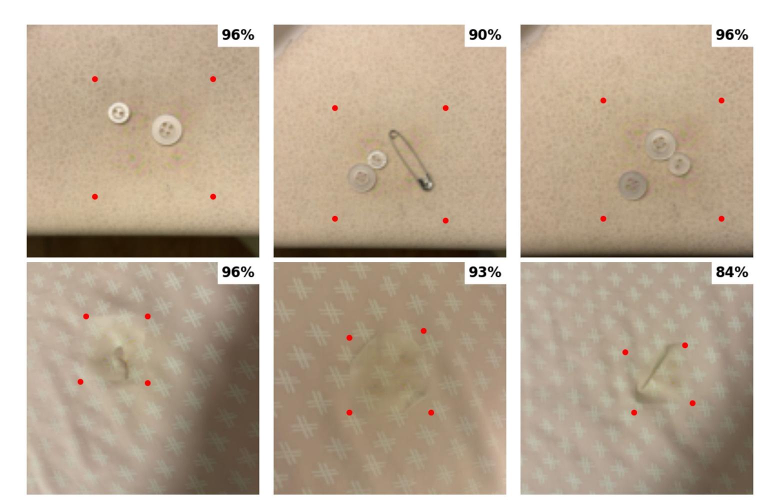
Real-world:

- Dataset of 34 encoded surfaces, 84 images total, with a variety of imaging conditions.
- Average decoding accuracy of 93.10% and median accuracy of 94%.



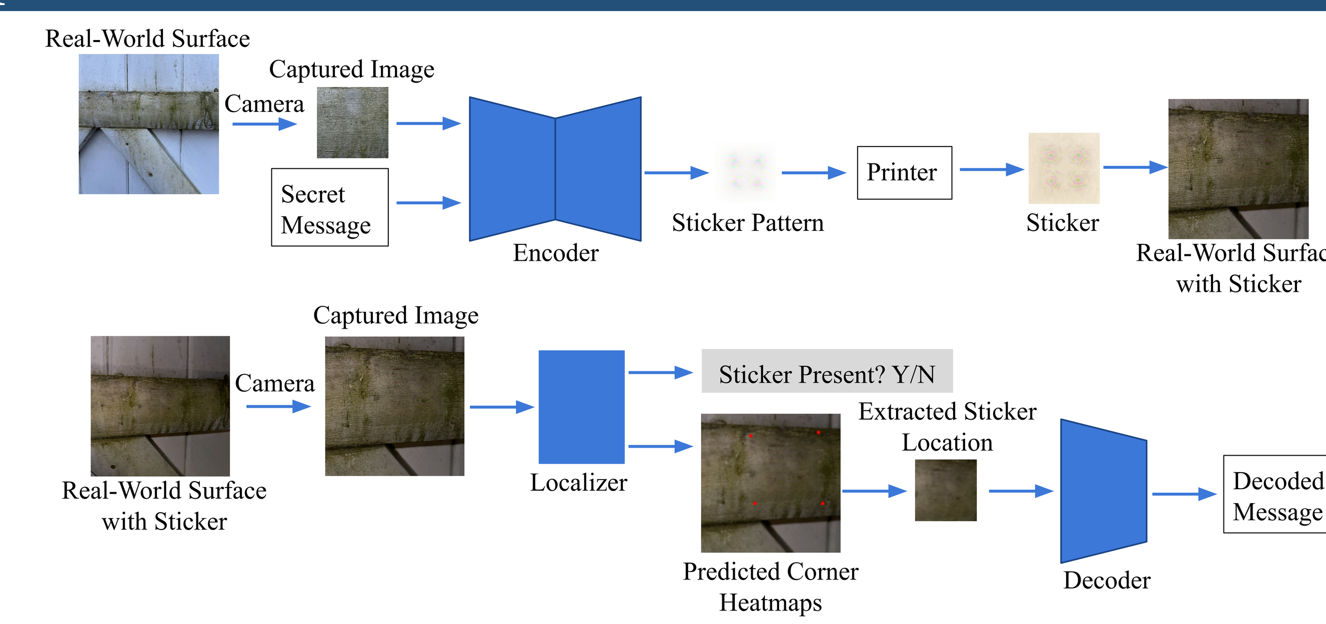


Multi-sticker detection



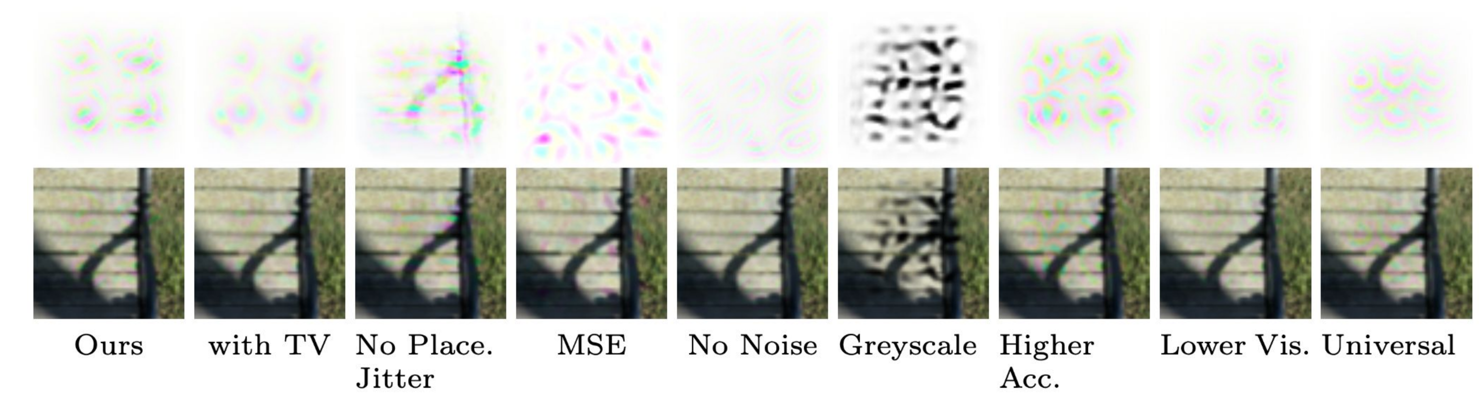
Robust to occlusion and wrinkles

Pipeline



Ablations

- Experimented with how removing or modifying components of the loss function influenced our evaluation metrics.



Method	Decode Acc. ↑	LPIPS ↓	Class. Acc. ↑
Ours	89.16%	0.0632	97.24%
With TV	84.20%	0.0428	94.04%
No Placement Jitter	86.85%	0.0557	96.69%
MSE	89.11%	0.1111	95.76%
No Noise	90.22%	0.0125	46.45%
Greyscale	93.79%	0.2132	99.81%
Higher Accuracy	94.80%	0.1099	98.10%
Lower Visibility.	81.93%	0.0290	89.73%
Universal	87.89%	0.0667	94.36%

References

[1] Jia, J., Gao, Z., Zhu, D., Min, X., Zhai, G., Yang, X.: Learning invisible markers for hidden codes in offline-to-online photography. In: IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). pp. 2263–2272 (2022). https://doi.org/10.1109/CVPR52688.2022.00231

[2] Ronneberger, O., Fischer, P., Brox, T.: U-net: Convolutional networks for biomedical image segmentation. In: Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015. pp. 234–241. Springer International Publishing (2015)

[3] Tancik, M., Mildenhall, B., Ng, R.: Stegastamp: Invisible hyperlinks in physical photographs. In: IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). pp. 2117–2126 (2020)

[4] Wang, J., Sun, K., Cheng, T., Jiang, B., Deng, C., Zhao, Y., Liu, D., Mu, Y., Tan, M., Wang, X., et al.: Deep high-resolution representation learning for visual recognition. IEEE transactions on Pattern Analysis and Machine Intelligence 43(10), 3349–3364 (2020). https://doi.org/10.1109/TPAMI.2020.2983686

[5] Zhang, R., Isola, P., Efros, A.A., Shechtman, E., Wang, O.: The unreasonable effectiveness of deep features as a perceptual metric. In: IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). pp. 586–595 (2018). https://doi.org/10.1109/CVPR.2018.00068