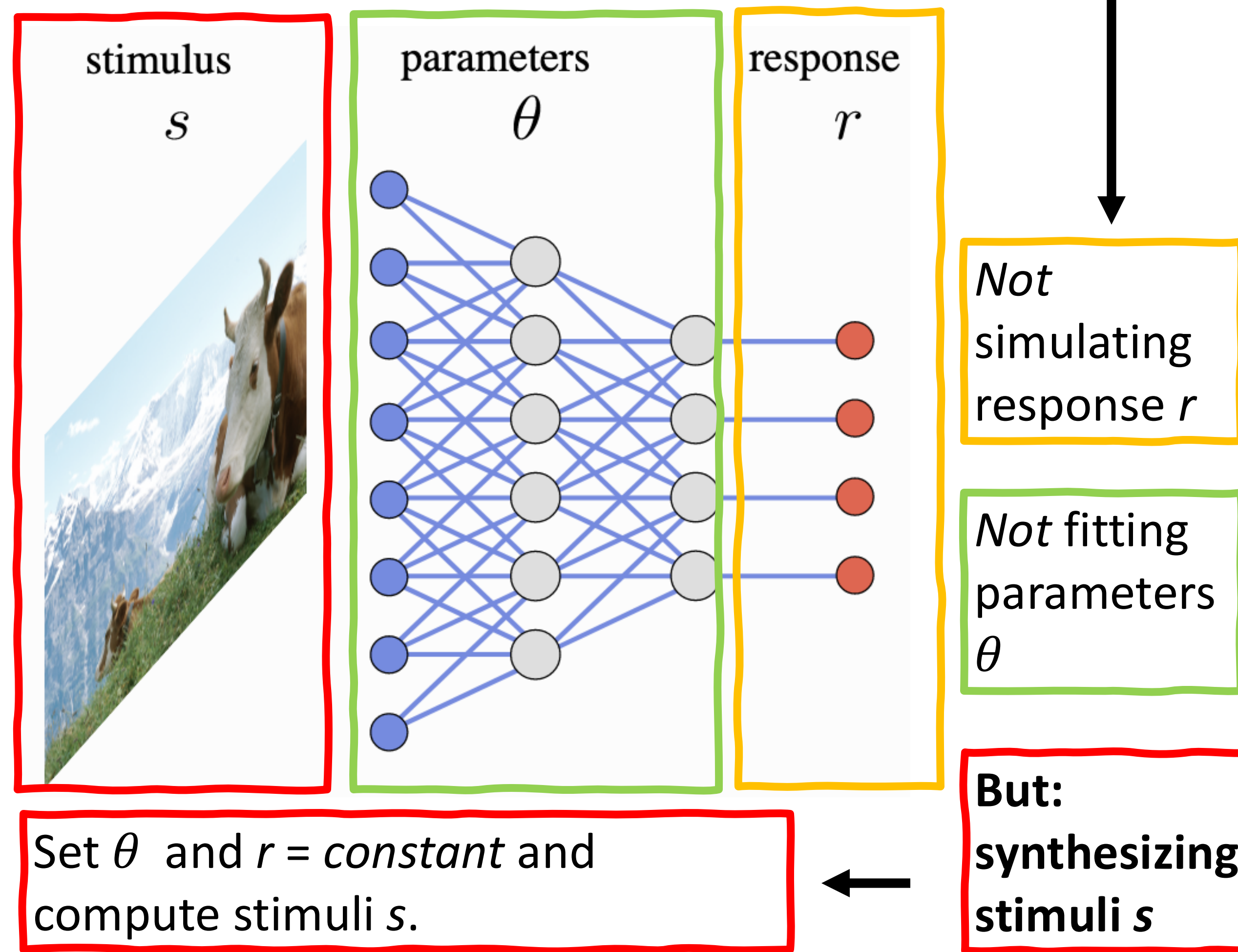# Understanding Visual Models with plenoptic

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1. Center for Computational Neuroscience, Flatiron Institute, New York
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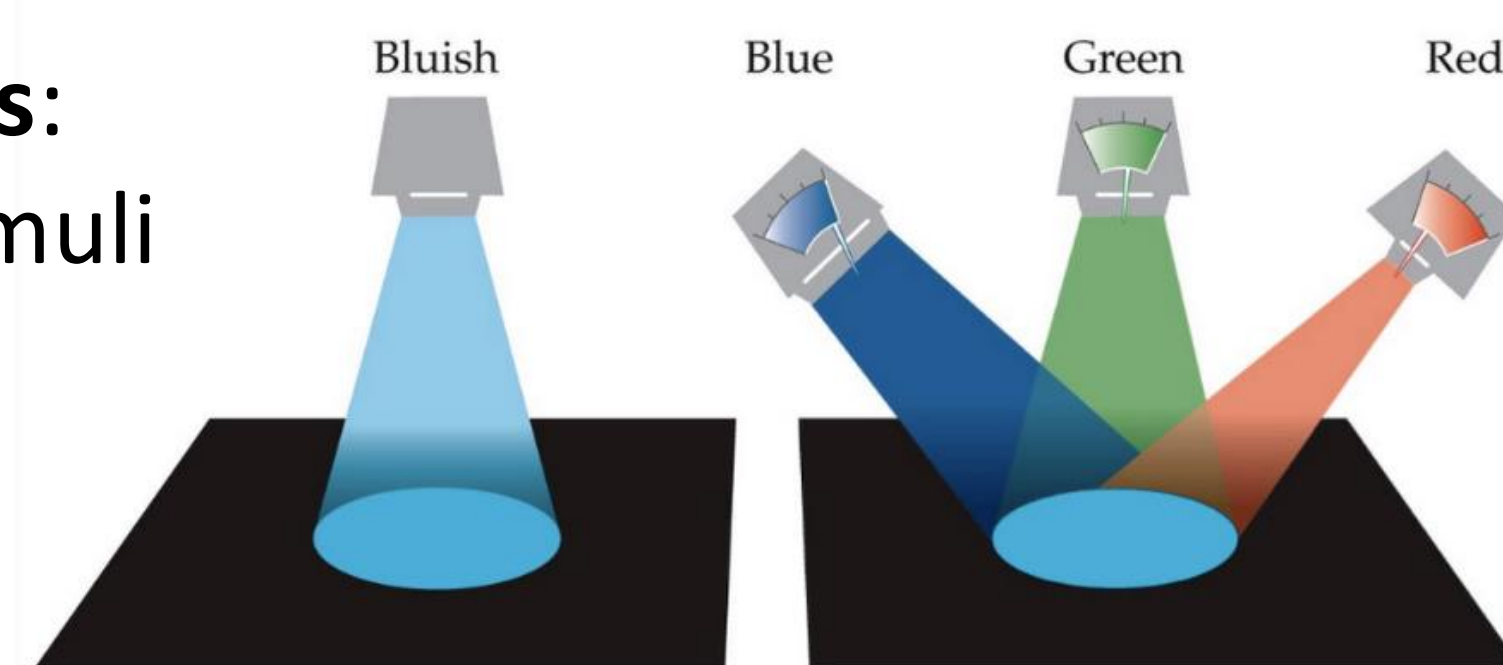3. Department of Computer Science, University of Tübingen, Germany

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input → BLACK BOX → output

plenoptic[1] in a Nutshell

Goal: facilitate model understanding

stimulus s — parameters θ — response r

Not simulating response r

Not fitting parameters θ

Set θ and r = *constant* and compute stimuli s.

But: synthesizing stimuli s

Metamers

Perceptual Metamers:
Physically distinct stimuli but *perceptually* the same.

Model Metamers:
Physically distinct but same model representation.

Another example:
Adversarial examples (Szegedy et al. (2013)): Perceptual metamers to humans are *not* metamers for the model.

Color matching experiment as an example for **perceptual metamers.**

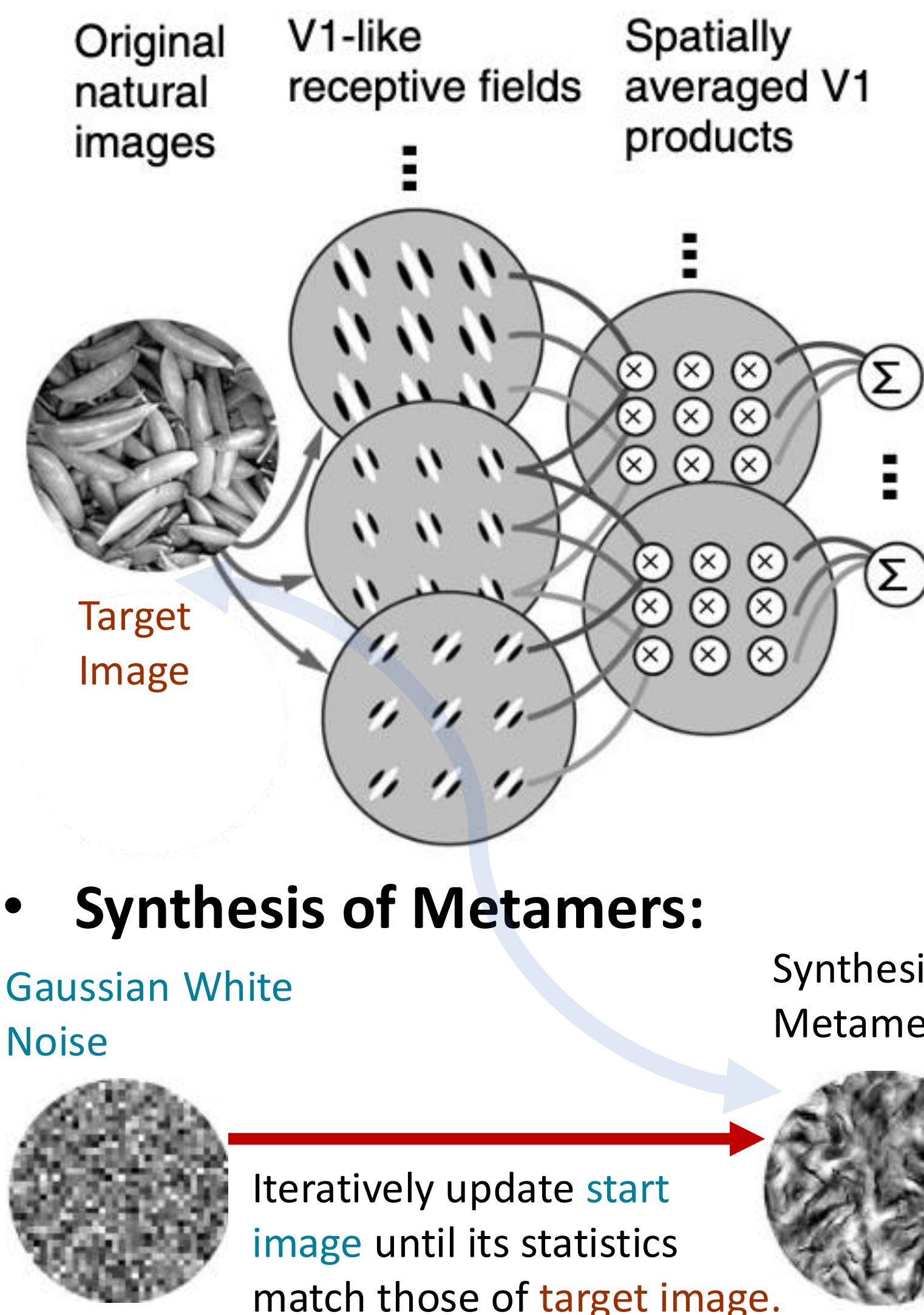Correctly classified — Additive noise — Classified as "Ostrich"

Portilla-Simoncelli Model[2]

What is visual texture?
- A repeating visual pattern (e.g., the web of a basket)

The Portilla-Simoncelli Model:
- **Purpose:** to evaluate if model metamers are similar to perceptual (human) metamers.
- **Output:** a tensor summarizing "texturiness" of image.
- **Advantage:** *compact*: "only" has 710 parameters vs. 130 mio. (VGG19) & *interpretable*.

Original natural images — V1-like receptive fields — Spatially averaged V1 products

Target Image

• Synthesis of Metamers:

Gaussian White Noise → Synthesized Metamer

Iteratively update start image until its statistics match those of target image.

Background: 3 Different Color Spaces

- **RGB**: Used in screens and cameras, based on mixing red, green, and blue light.
- **Long, Medium, Short (LMS)**: Based on how our eyes perceive colors using different types of cone cells (L, M, S).
- **Opponent Process Color (OPC)**: Based on how our brain processes colors in opposing pairs.

RGB — LMS — OPC

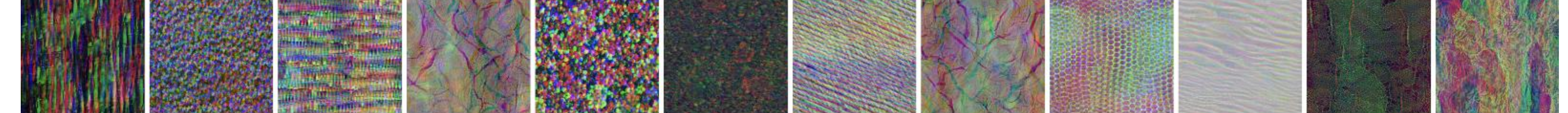
Extending the Model to Synthesize Better Color Images[3]
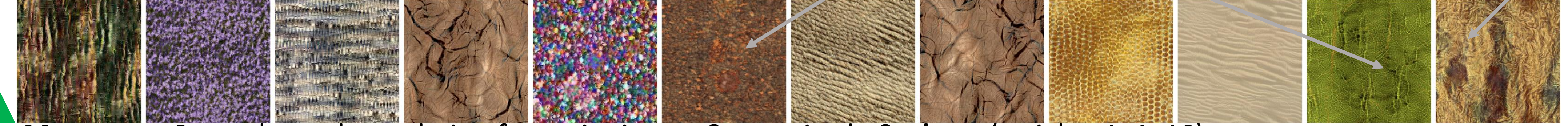
Target Texture Images:

Metamers: Original P-S Model

Metamers: Original Model on **OPC-transformed images**

Metamers: Additional **Cross-channel Correlation** on Image (weight 10)

Eliminates dominant red.

Metamers: Cross channel correlation for entire image & magnitude & **phase** (weights 1, 1, 10)
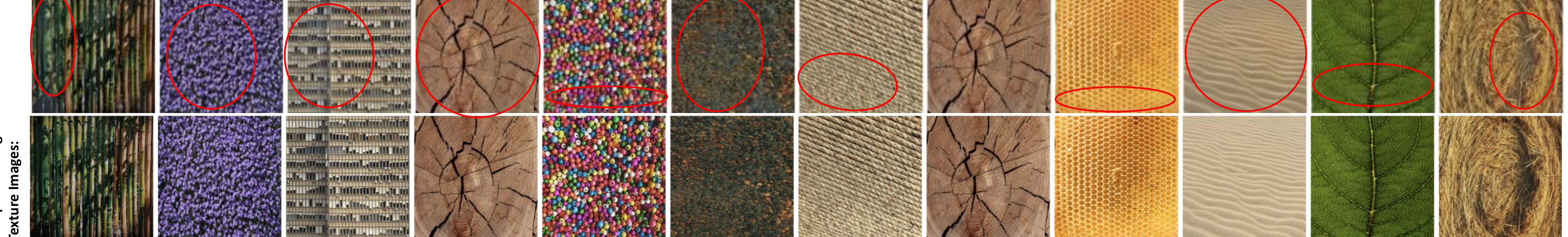
Metamers: Cross channel correlation for entire image & **magnitude** & phase (weights 1, 10, 1)

Comparison to a DNN:
Style-Transfer[4]: Initialization: style image = content image, output image = Gaussian noise

Slightly blurry & color contrast slightly off compared to original images.
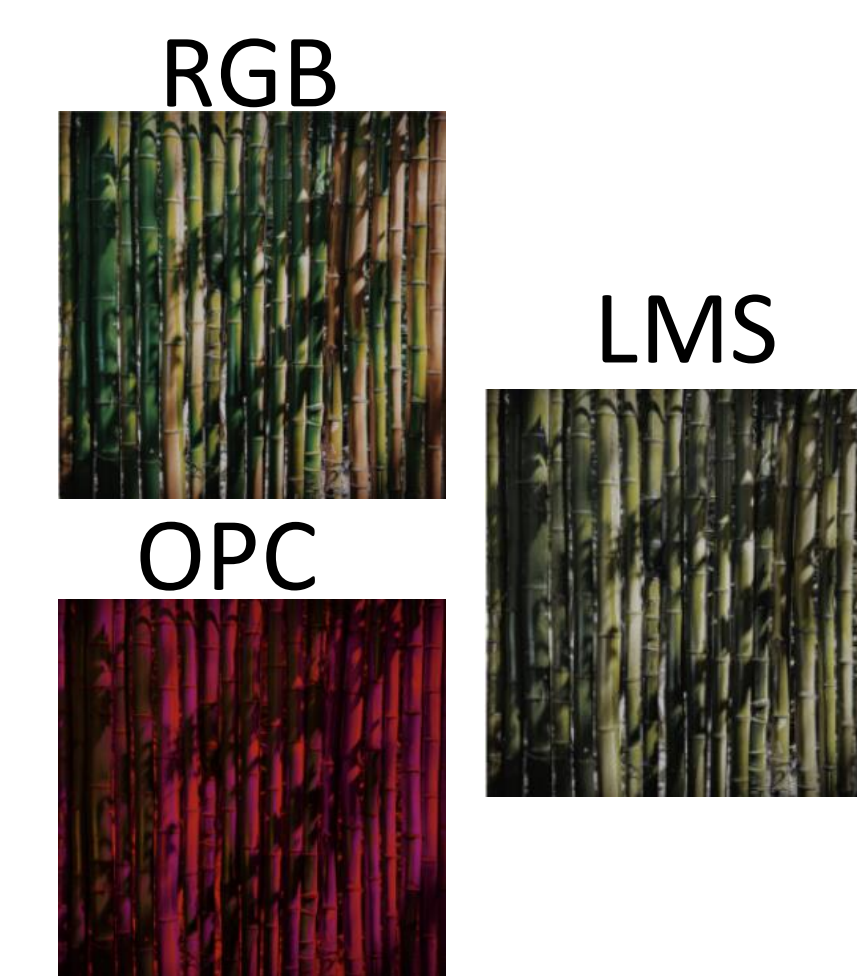
Compare to Target Texture Images:

Outlook & Future Work

- Instead of averaging over entire image, generate image statistics based on smaller pooling windows [3].
- Add end of line statistics as in [3].

References

[1] Lyndon Duong, Kathryn Bonnen, William Broderick, Pierre-Étienne Fiquet, Nikhil Parthasarathy, Thomas Yerxa, Xinyuan Zhao, Eero Simoncelli; Plenoptic: A platform for synthesizing model-optimized visual stimuli. Journal of Vision 2023;23(9):5822. https://doi.org/10.1167/jov.23.9.5822.

[2] Portilla, J., & Simoncelli, E. P. (2000). A parametric texture model based on joint statistics of complex wavelet coefficients. International journal of computer vision, 40(1), 49–70

[3] Rachel Brown, Vasha Dutell, Bruce Walter, Ruth Rosenholtz, Peter Shirley, Morgan McGuire, and David Luebke. 2023. Efficient Dataflow Modeling of Peripheral Encoding in the Human Visual System. ACM Trans. Appl. Percept. 20, 1, Article 1 (January 2023), 22 pages. https://doi.org/10.1145/3564605

[4] Gatys, Leon A., Alexander S. Ecker, and Matthias Bethge. "A neural algorithm of artistic style." arXiv preprint arXiv:1508.06576 (2015).