UNIVERSITY OF FORWARD THINKING WESTMINSTER

Bridging the gap between image quality & image aesthetics

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Image Quality

“*degree of excellence of an* ***image***” (Roufs, 1992) “*not directly related to the physical image itself but to its* ***internal or mental representation*** *(sensory image)*” (de Ridder, et al, 1995)

“the **subjective impression** found in the mind of the observer relating to the degree of excellence exhibited by an **image**” (Jacobson, 1995)

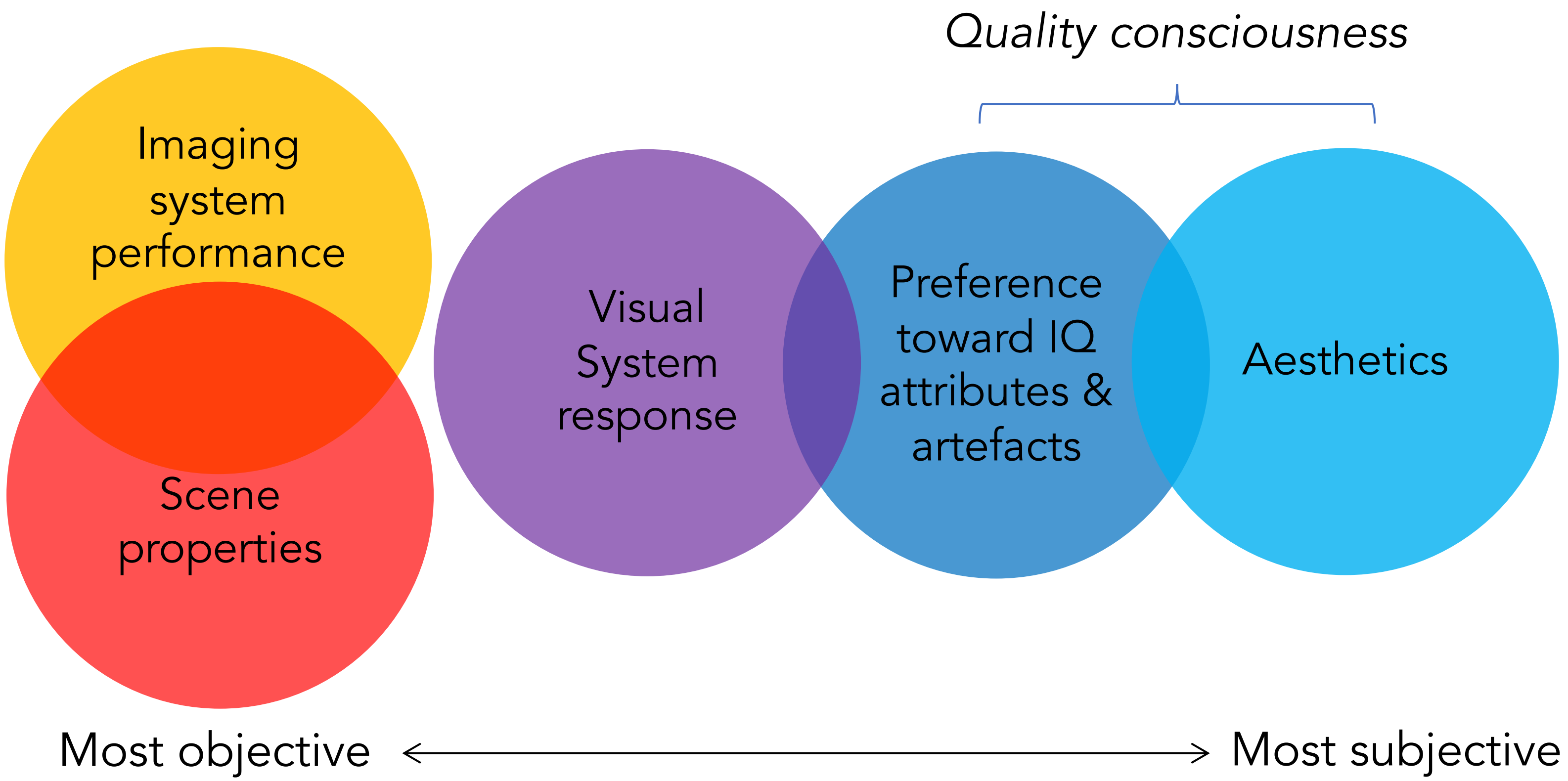
“*the* ***integrated set of perceptions*** *of the overall degree of excellence of the* ***image***” (Engeldrum, 1999)

“*the* ***impression*** *of the overall merit or excellence of an* ***image****, as* ***perceived by an observer*** *neither associated with the act of photography, nor closely involved with the subject matter depicted*” (Keelan, 2002 – ISO 20462:2005)

Elements affecting image quality

Adapted from Fry, E. & Triantaphillidou, S., 2019

Elements affecting image quality



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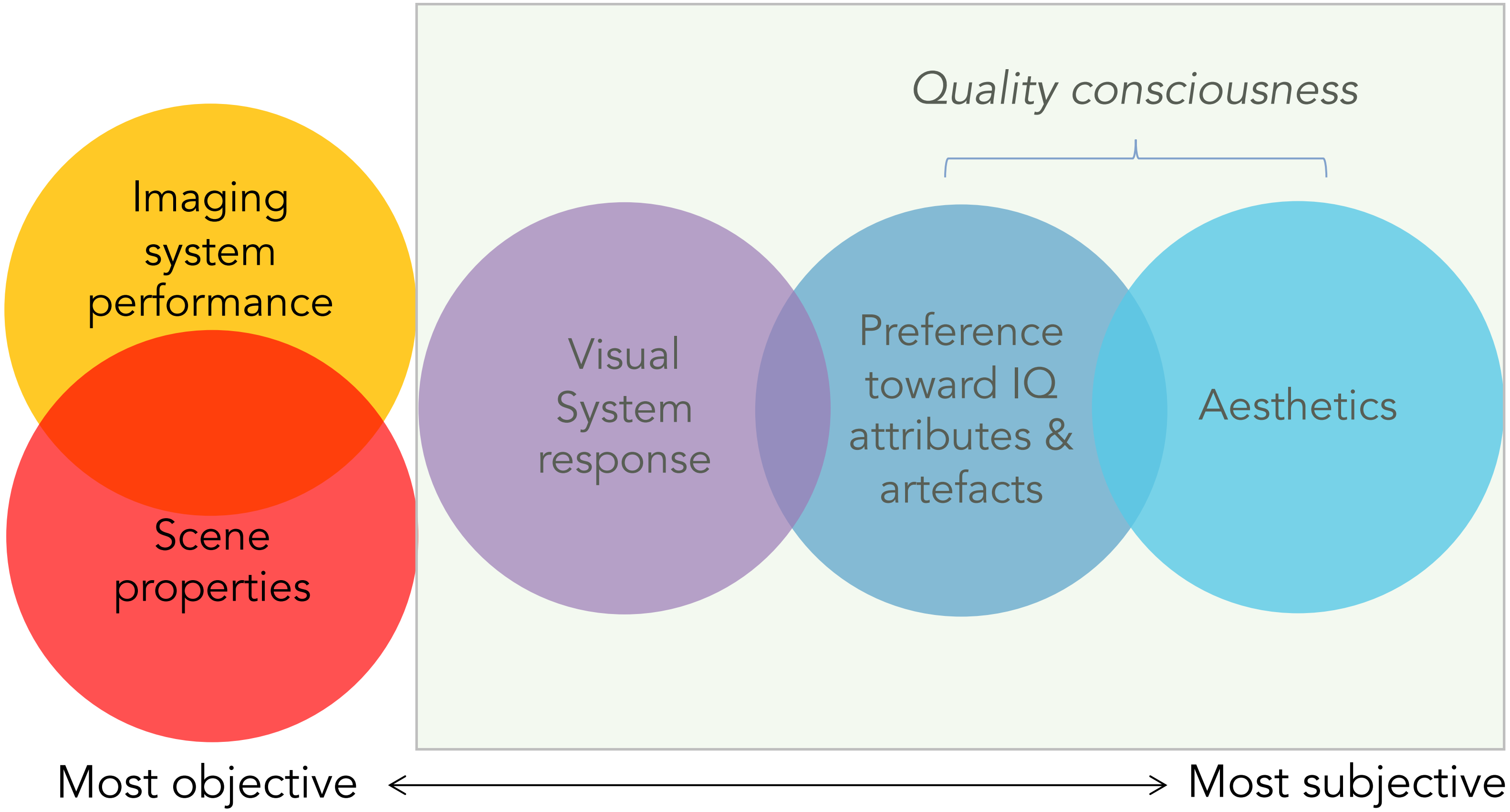

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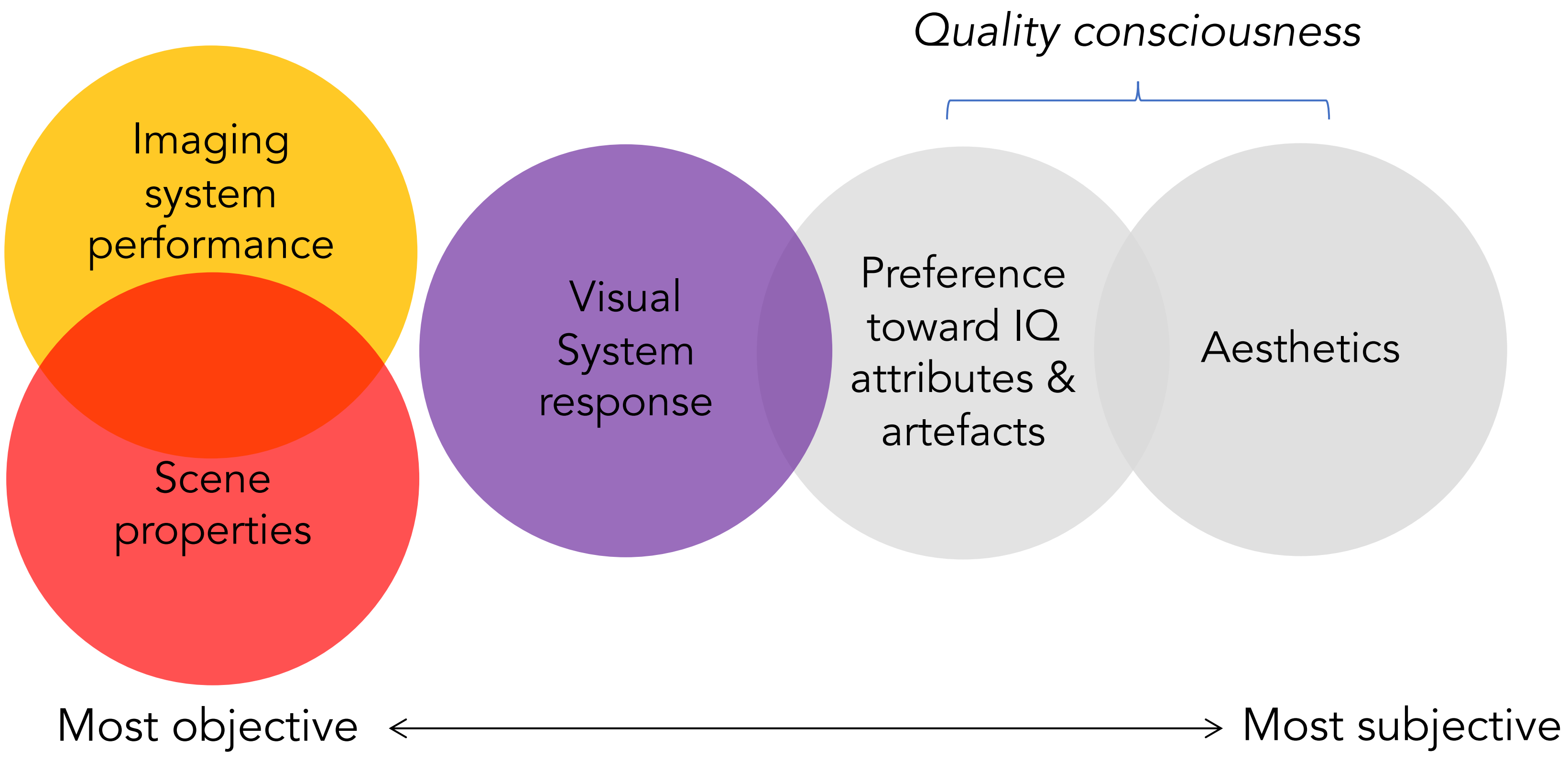

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Subjective image quality evaluation

- Visual psychophysics (*the relationship between physical signals (images) vs their sensory representation)*
- Controlled environments
- Large number of observers
- Range of scene contents (large test image sets)
- Tedious, lengthy and expensive

Image Quality Metrics

“mathematical ***models*** *that produce* ***figures of merit****, aimed to predict* ***subjective image quality ratings*** *designated by observers”*

Image Quality Metrics

*"mathematical **models** that produce **figures of merit**, aimed to predict **subjective image quality ratings** designated by observers"*

- Engineering IQMs

(photographic/imaging science, optics, sensors communities)

- Computational IQMs

electrical engineering, computer science communities

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Digital camera IQ evaluation

Image Quality Metrics

Computational

predict visual quality from natural scene image data

or using natural scene models (statistics, regularities in natural environment)

Examples: from LIVE II dataset, Sheikh et all, 2006

Image Quality Metrics

Computational

predict visual quality from natural scene image data

or using natural scene models (statistics, regularities in natural environment)

do not use measures/models imaging system (or its components)

scene content dependent BUT imaging system independent

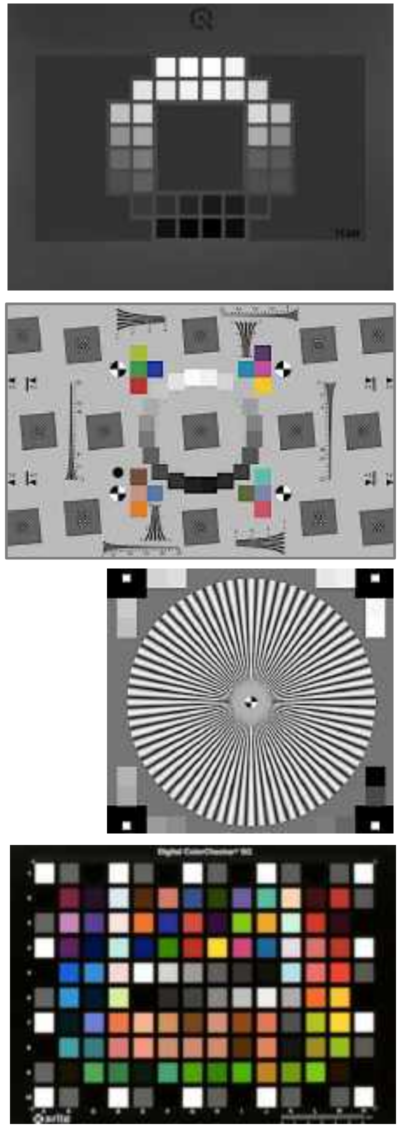
Examples: from LIVE II dataset, Sheikh et all, 2006

Image Quality Metrics

Engineering

predict visual quality from imaging system performance

measuring imaged test signals, or modelling imaging system parameters



Examples: charts from Image Engineering, Imatest, X-rite

Image Quality Metrics

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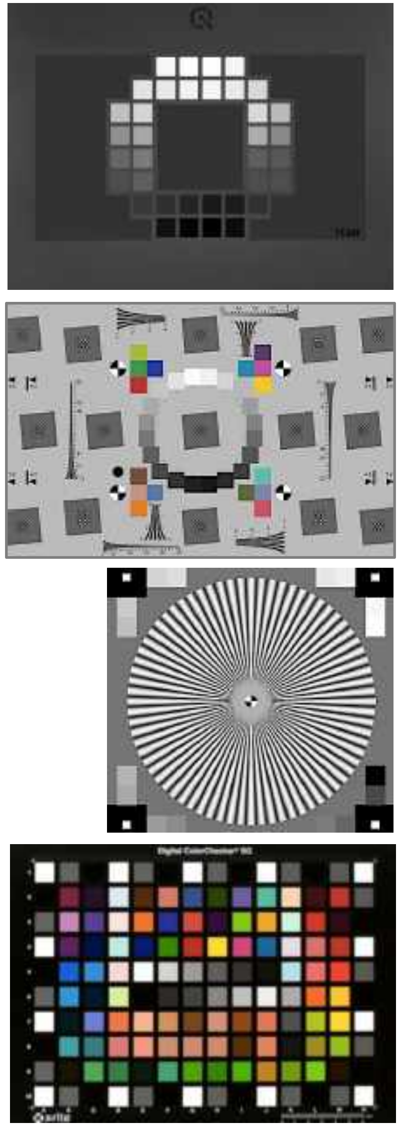
predict visual quality from imaging system performance

measuring imaged test signals, or modelling imaging system parameters

not concerned with individual scene/image contents

imaging system dependent BUT scene content independent



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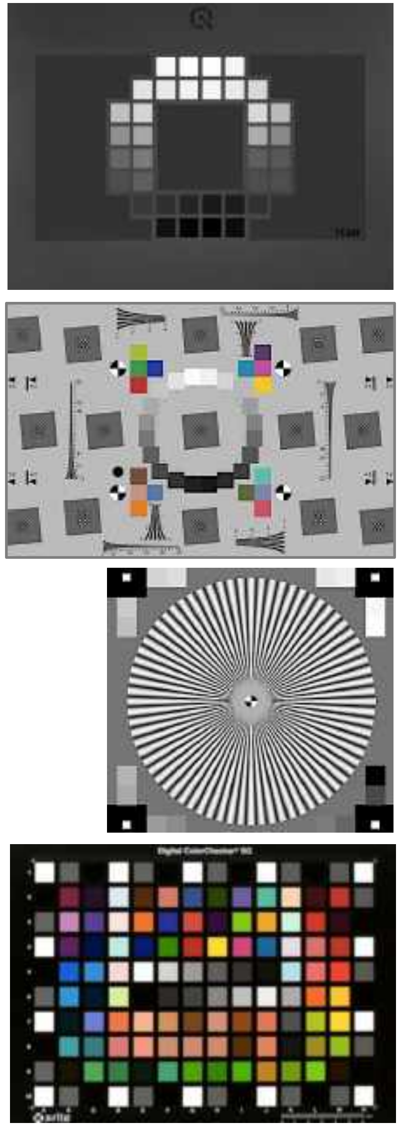

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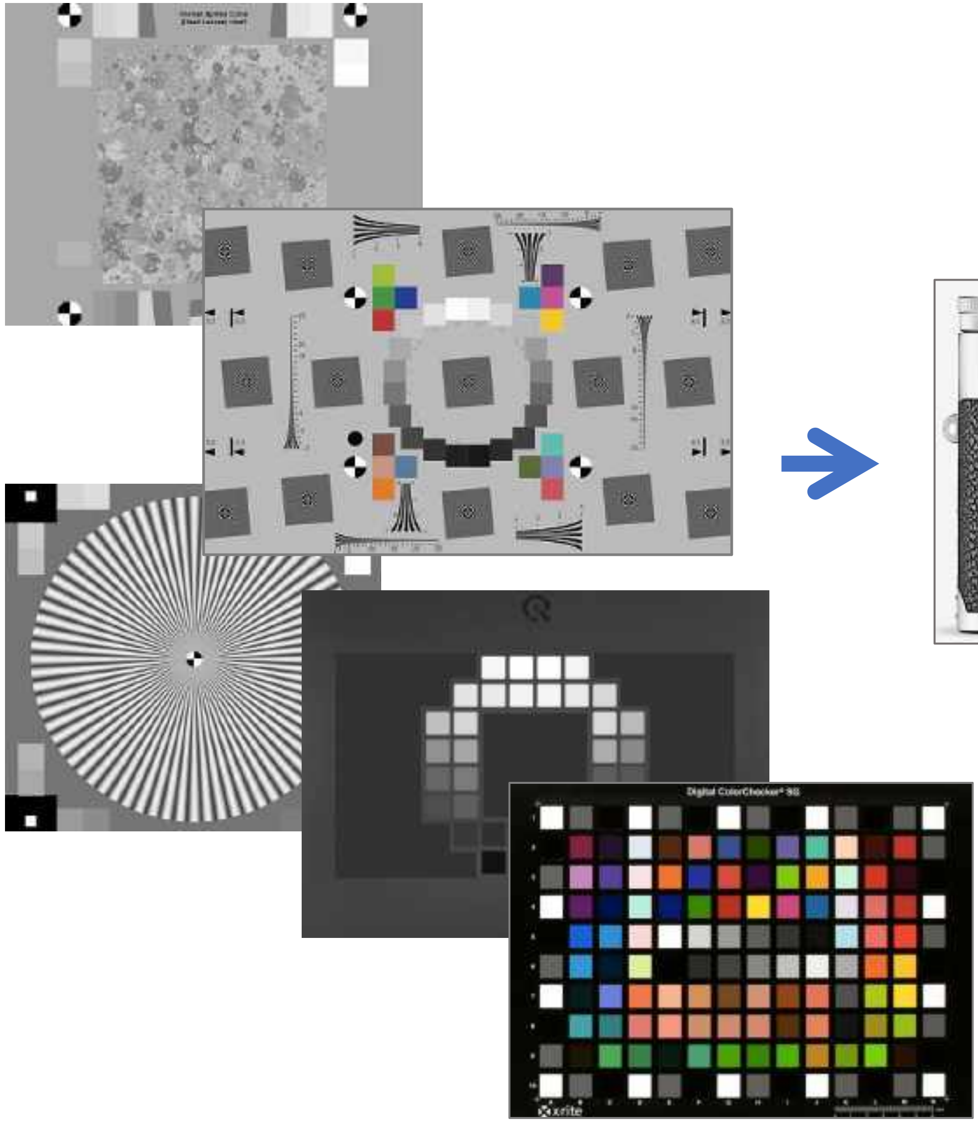
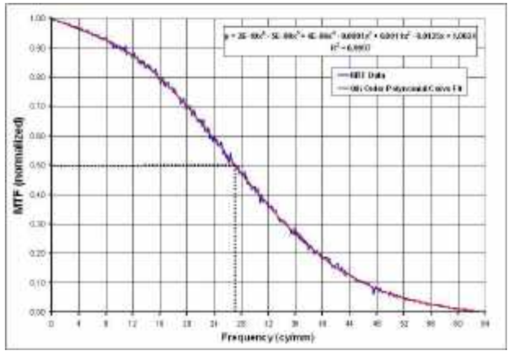
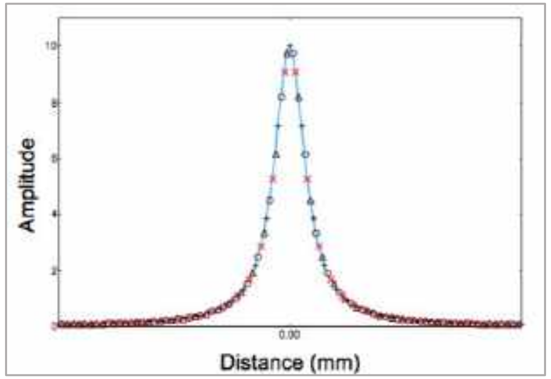
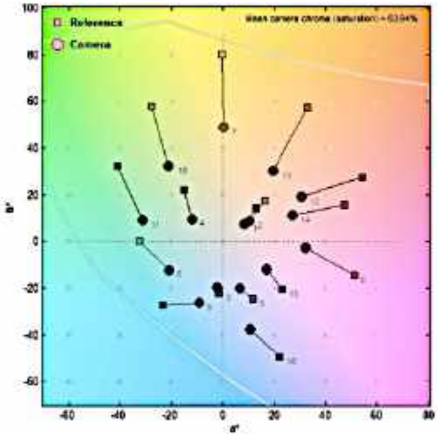
Camera system performance evaluation

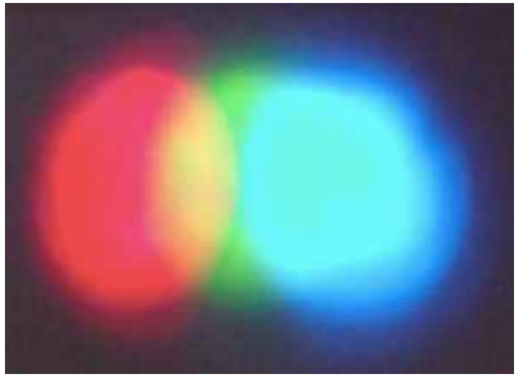


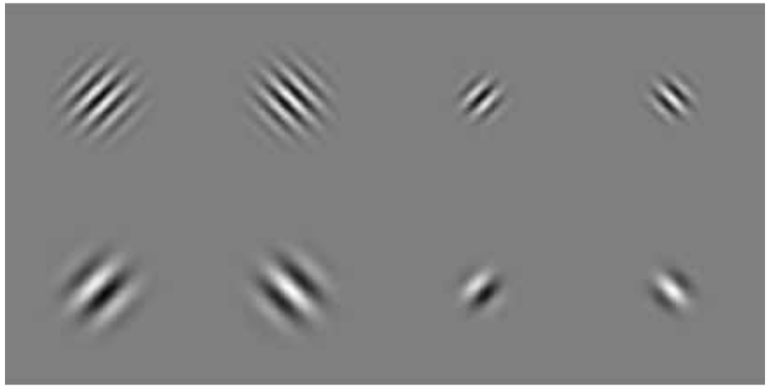


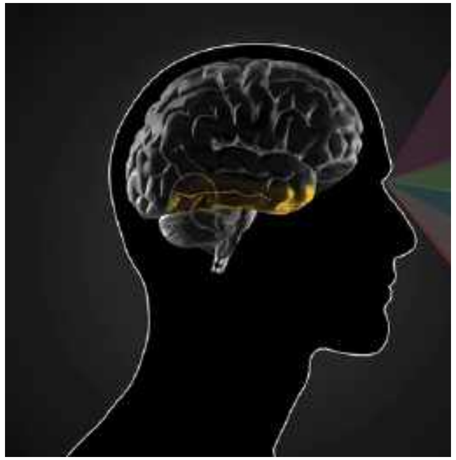


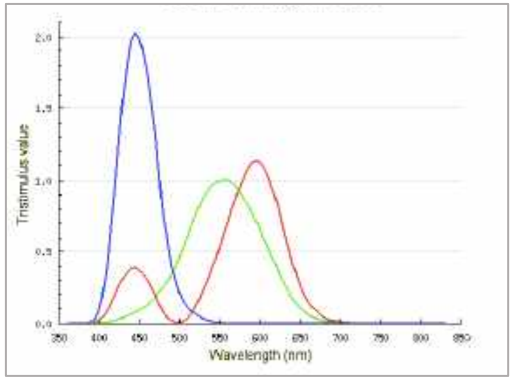


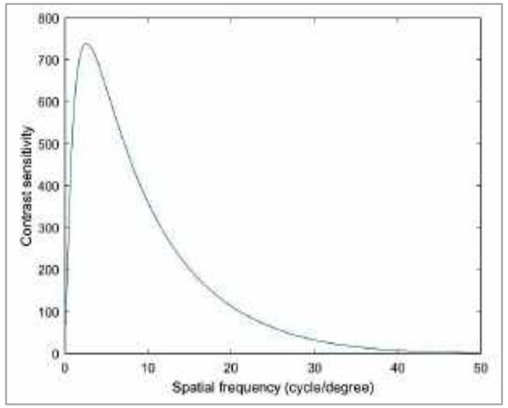
Visual system evaluation (low level vision)











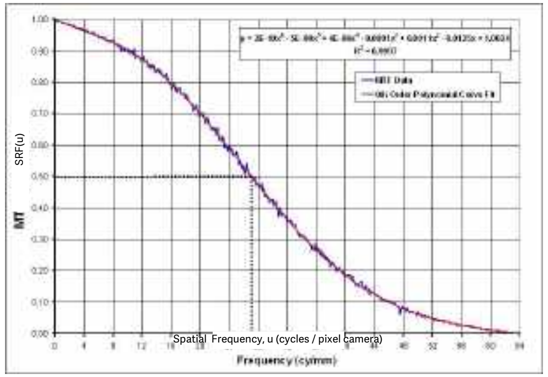
Engineering image quality modelling

Imaging performance measures →

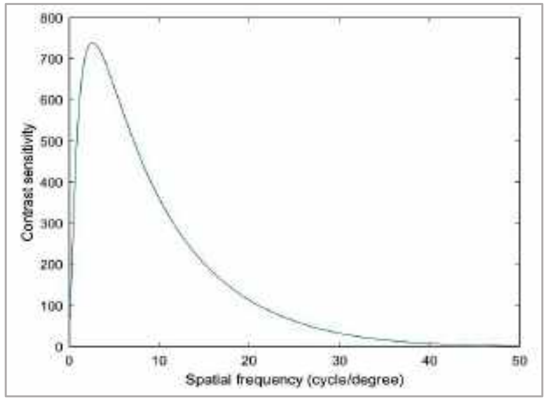
← Visual system models

Engineering image quality modelling

Camera MTF, $\boldsymbol{SFR(u)}$

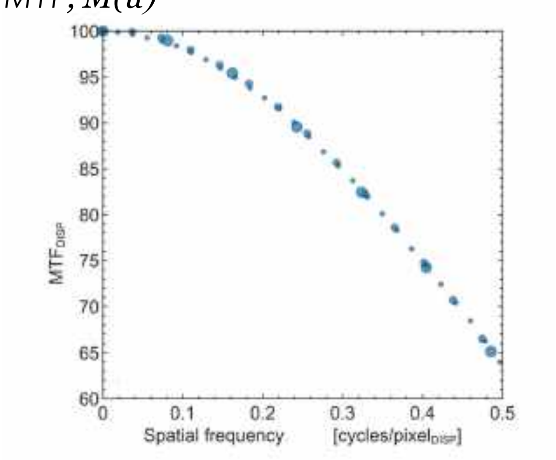


$\boldsymbol{CSF(\nu)}$



Imaging performance measures → Edge Acutance, $\boldsymbol{Q}$ **(sharpness) image quality metric** ← Visual system models

Display MTF, $M(u)$



Engineering image quality modelling

Imaging performance measures → **IEEE 1864: 2016 CPIQ** ← Visual system models

- edge and texture acutance
- visual noise
- texture blur
- chroma level
- total quality loss (QL)

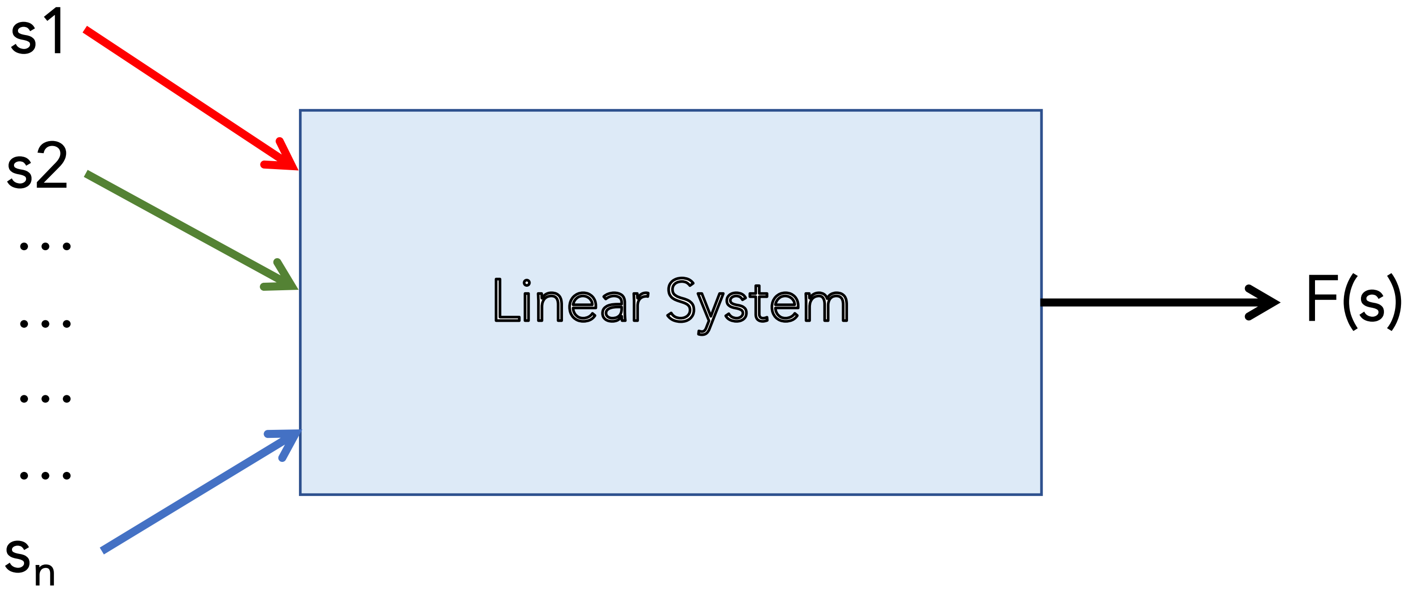
IEEE P2020 Automotive IQ

- edge acutance
- visual noise
- texture acutance
- visual flare

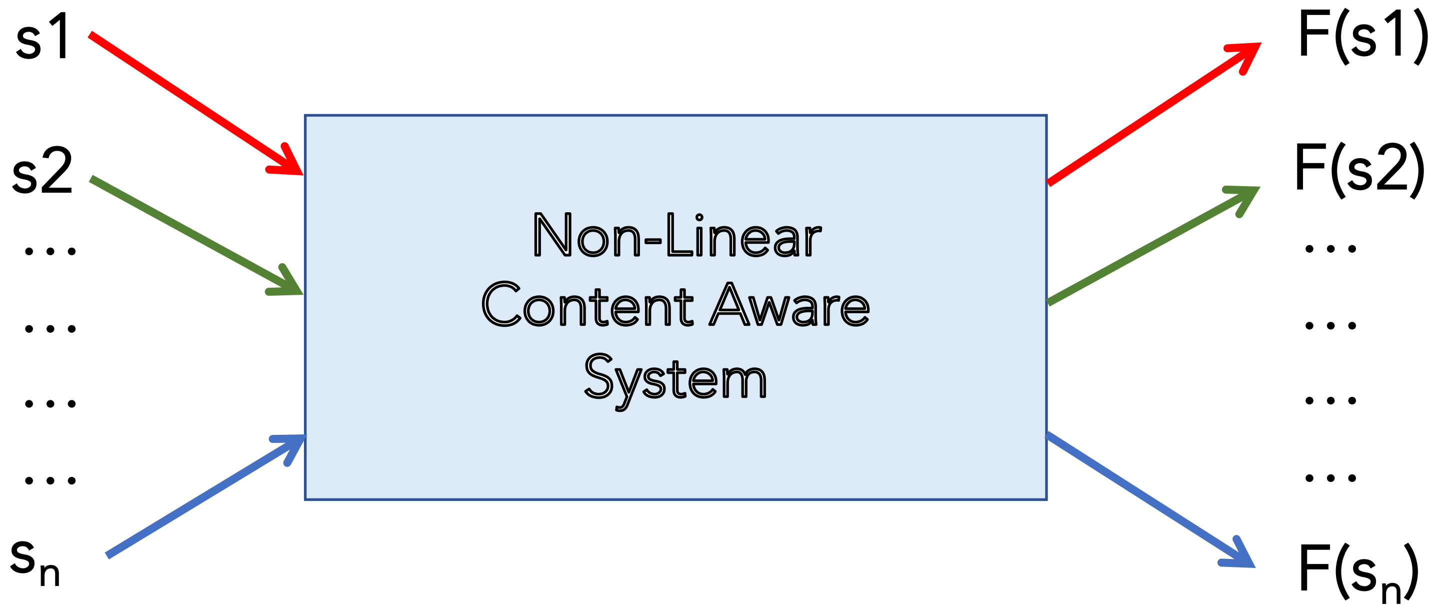
Others

- SQF
- SQRIn
- visual_NEQ
- visual_NPS
- ....

Linear vs non-linear content aware systems

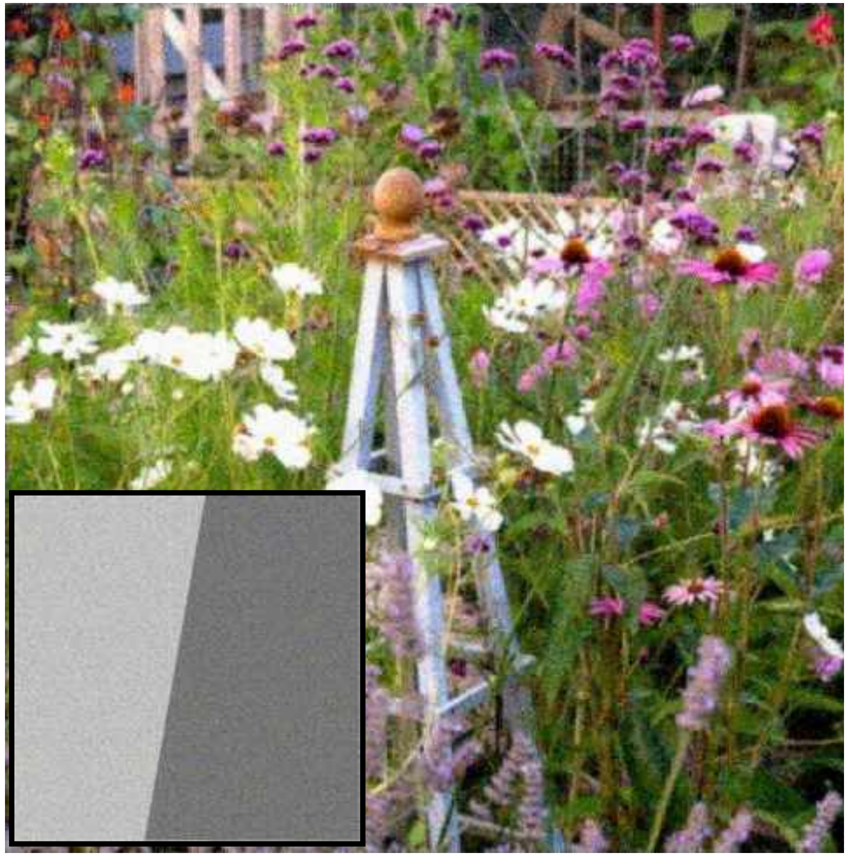


Linear vs non-linear content aware systems

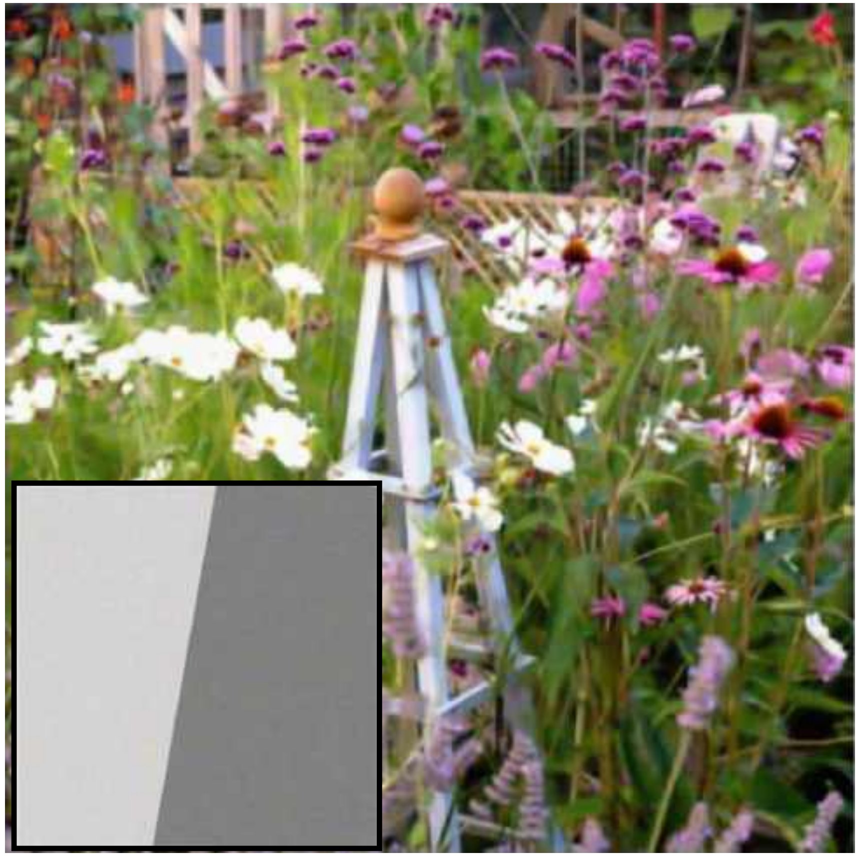


Scene dependent *sharpness* variations

Input



Output image
(after denoising)



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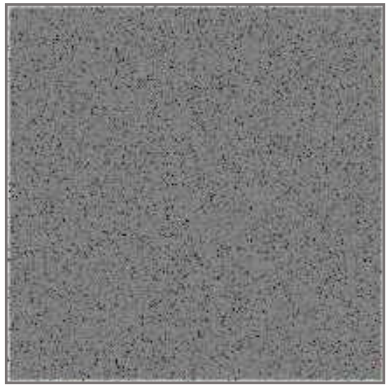

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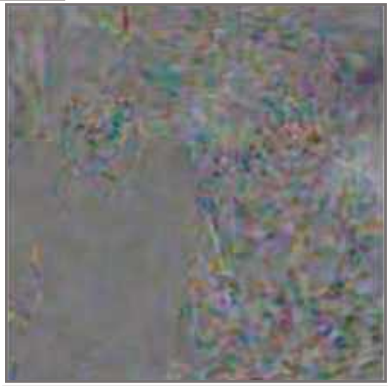

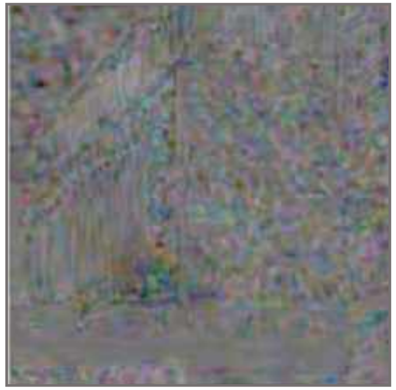

System & scene dependent image quality modeling

System & scene dependent image quality modeling

Use scene dependent *camera performance* measures:

- Conform to camera engineering methods and standards
- Extract useful test-signals directly from images (rather than test charts)
- Eliminate the use of specialized apparatus and laboratory conditions for camera evaluation

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Use scene dependent *camera performance* measures:

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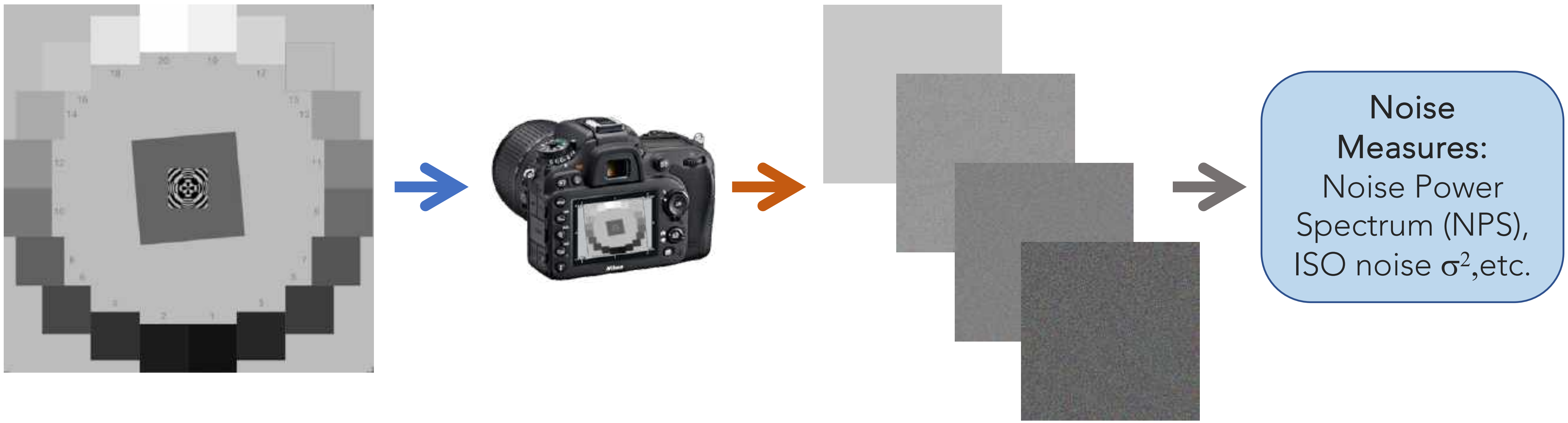
Camera *noise* measurement

Input test chart

Captured and isolated grey test patches

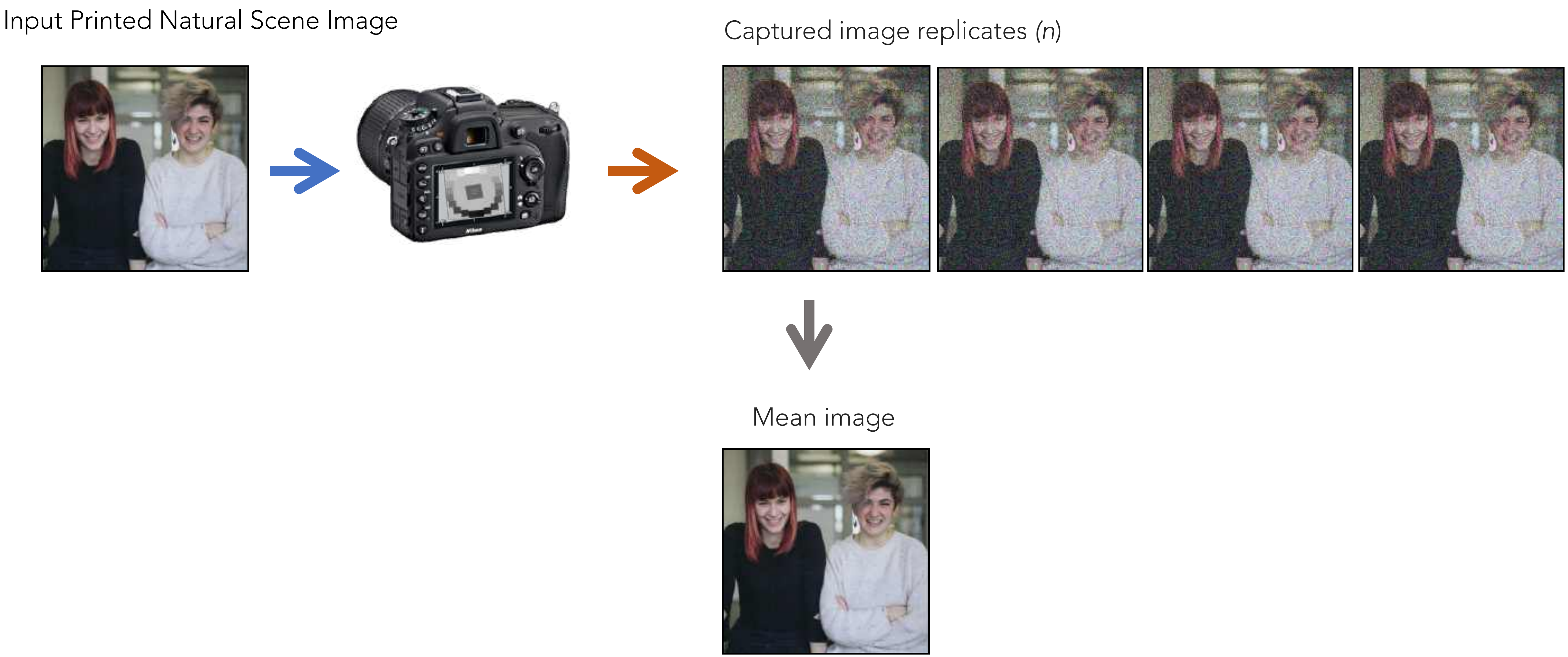


Camera *noise* measurement from *natural scene images*

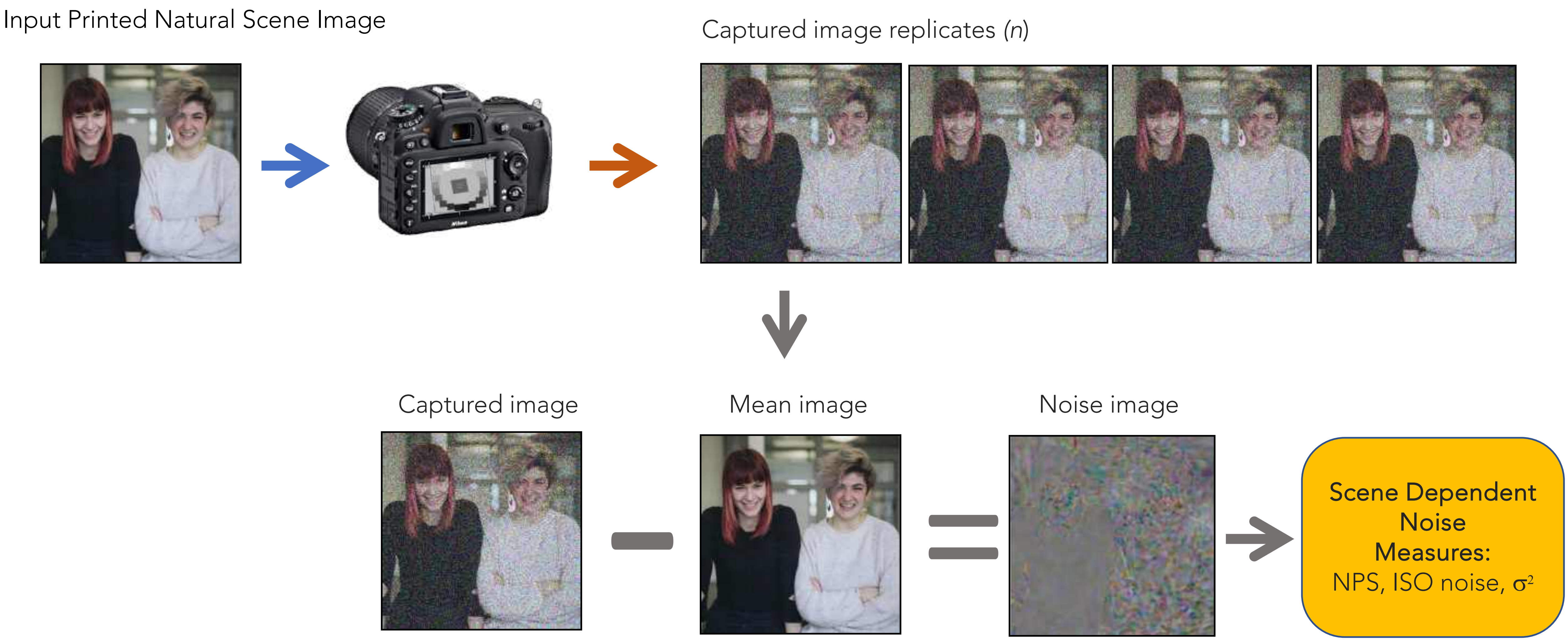
Input Printed Natural Scene Image

Captured image replicates (*n*)

Camera *noise* measurement from *natural scene images*

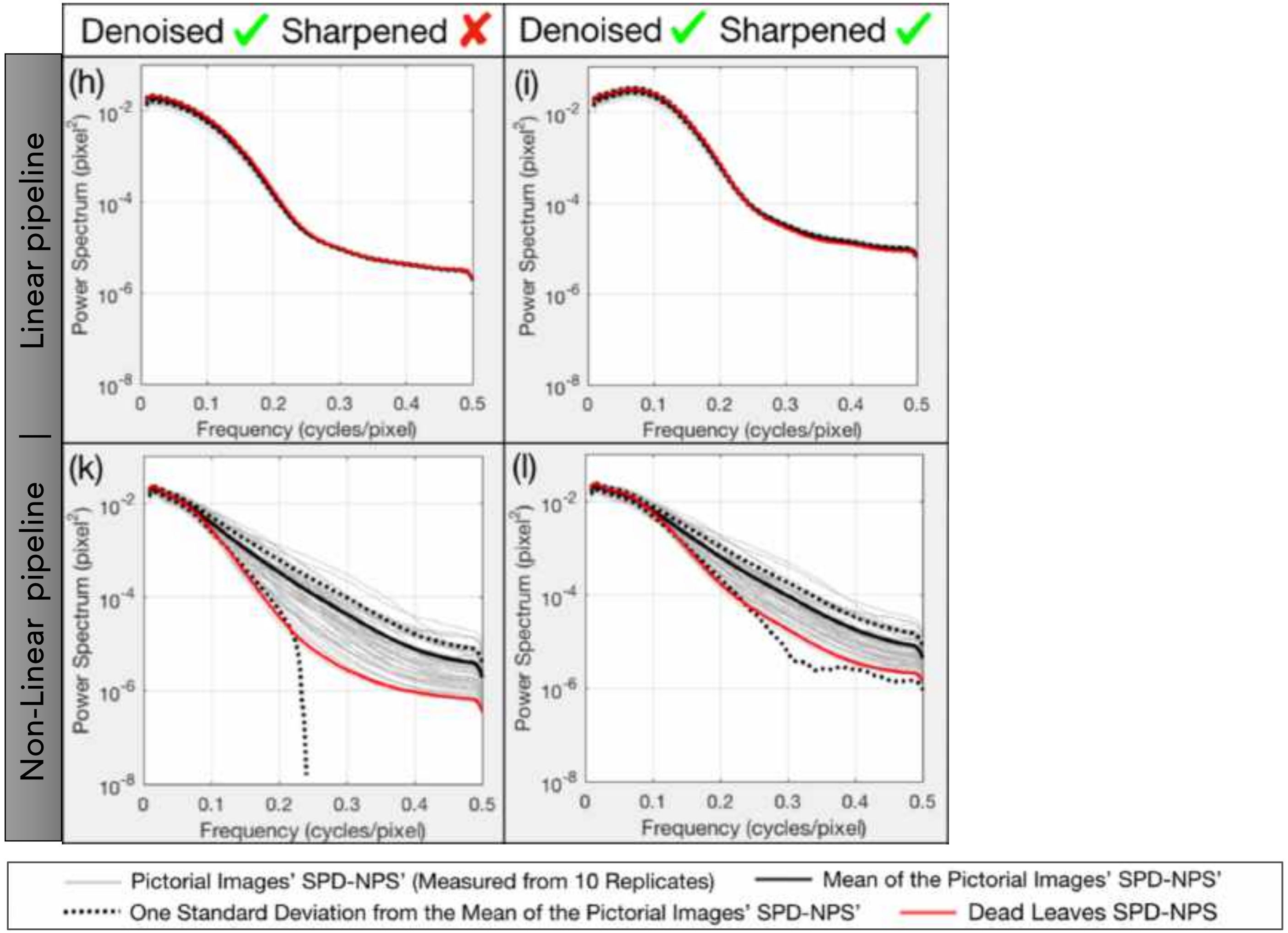


Camera *noise* measurement from *natural scene images*



Camera *noise* measurement from *natural scene images*

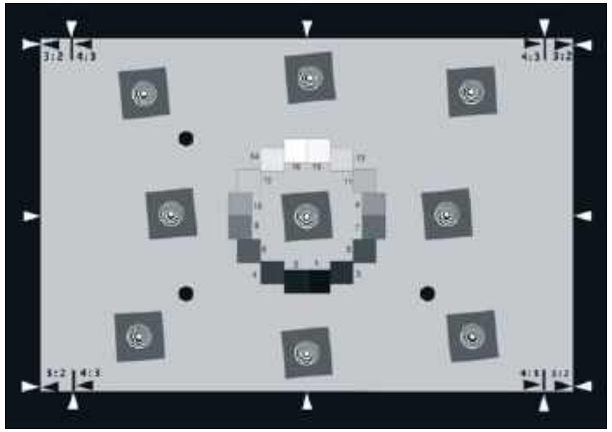
Simulated camera pipelines (@ SNR 5)



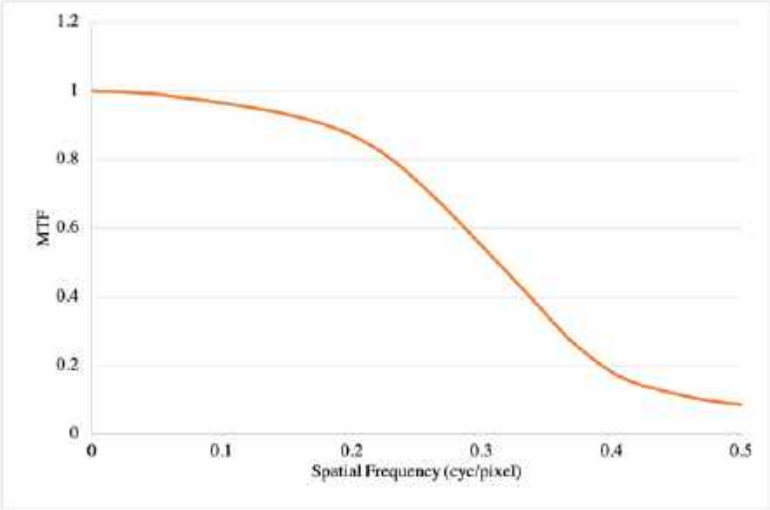
Fry, E S., Triantaphillidou, S., Jenkin, R. B., Jacobson, R. and Jarvis, J. R. (2019), *Validation of Modulation Transfer Functions and Noise Power Spectra from natural scenes*, JIST, 9, 60406-1-60406-11.

Camera *sharpness* measurement

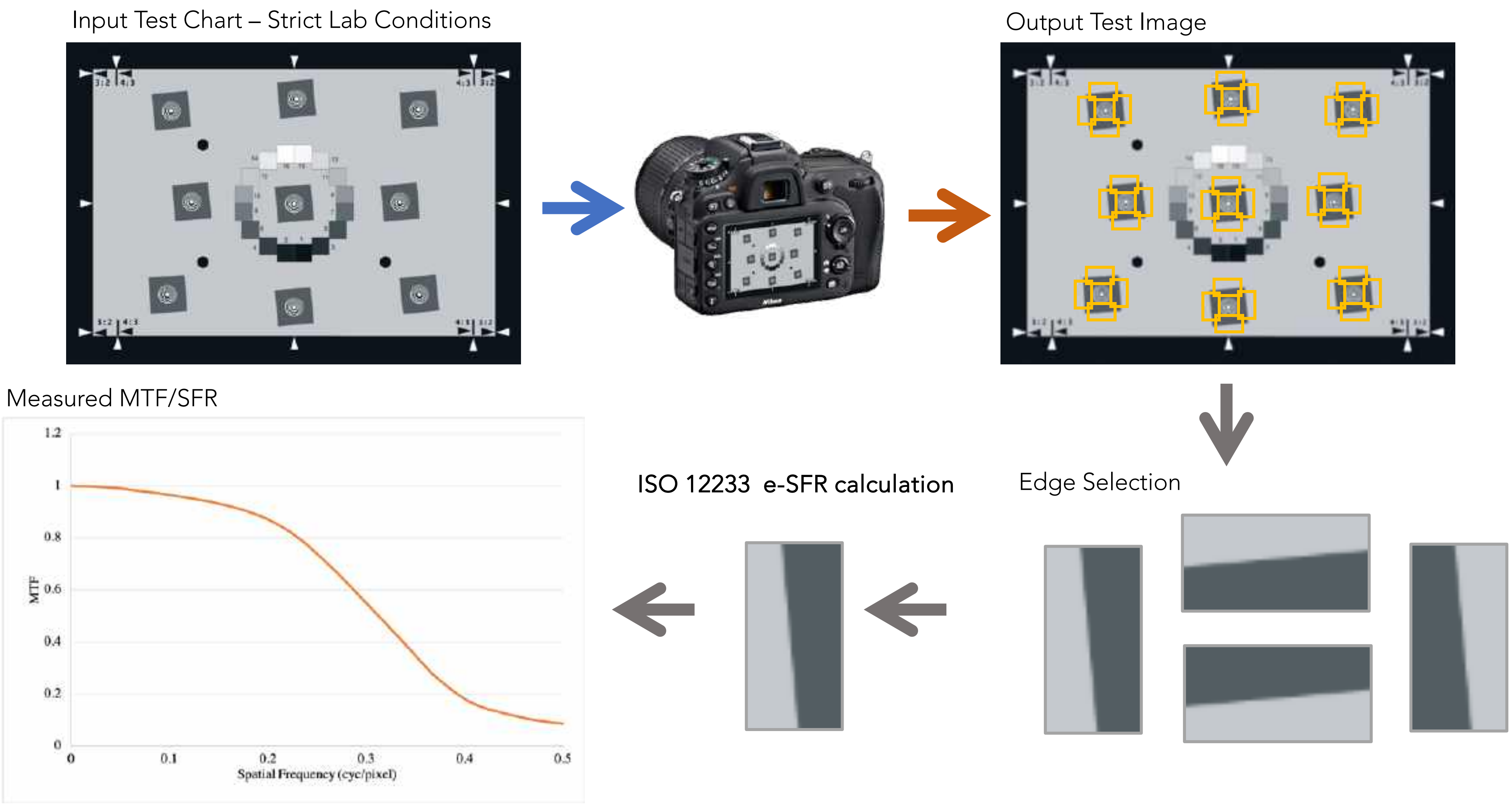
Input Test Chart – Strict Lab Conditions



Measured MTF/SFR

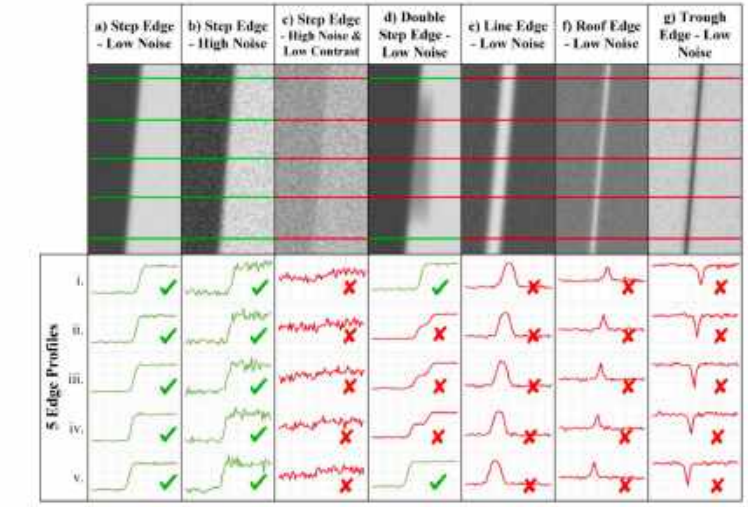


Camera *sharpness* measurement



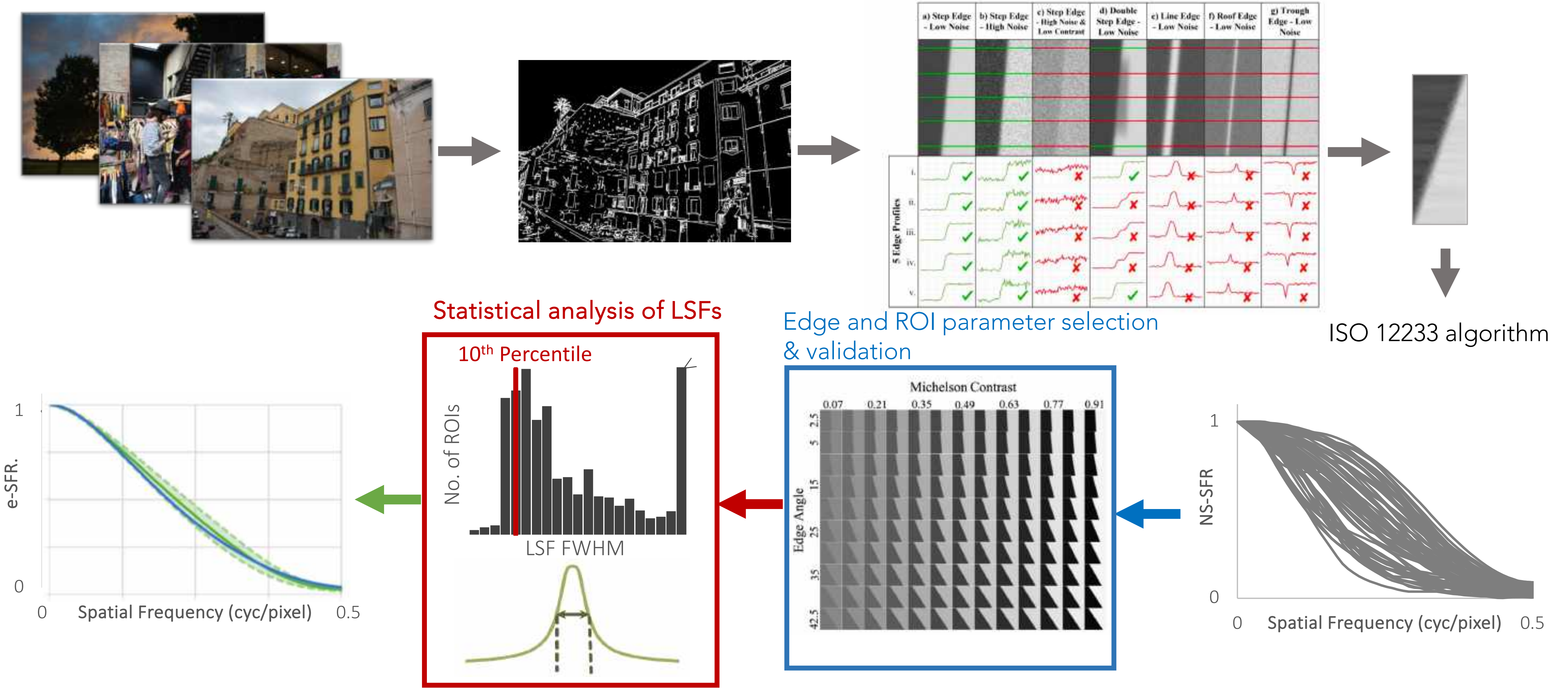
Camera *sharpness* measurement *from natural scenes*

Camera *sharpness* measurement *from natural scenes*



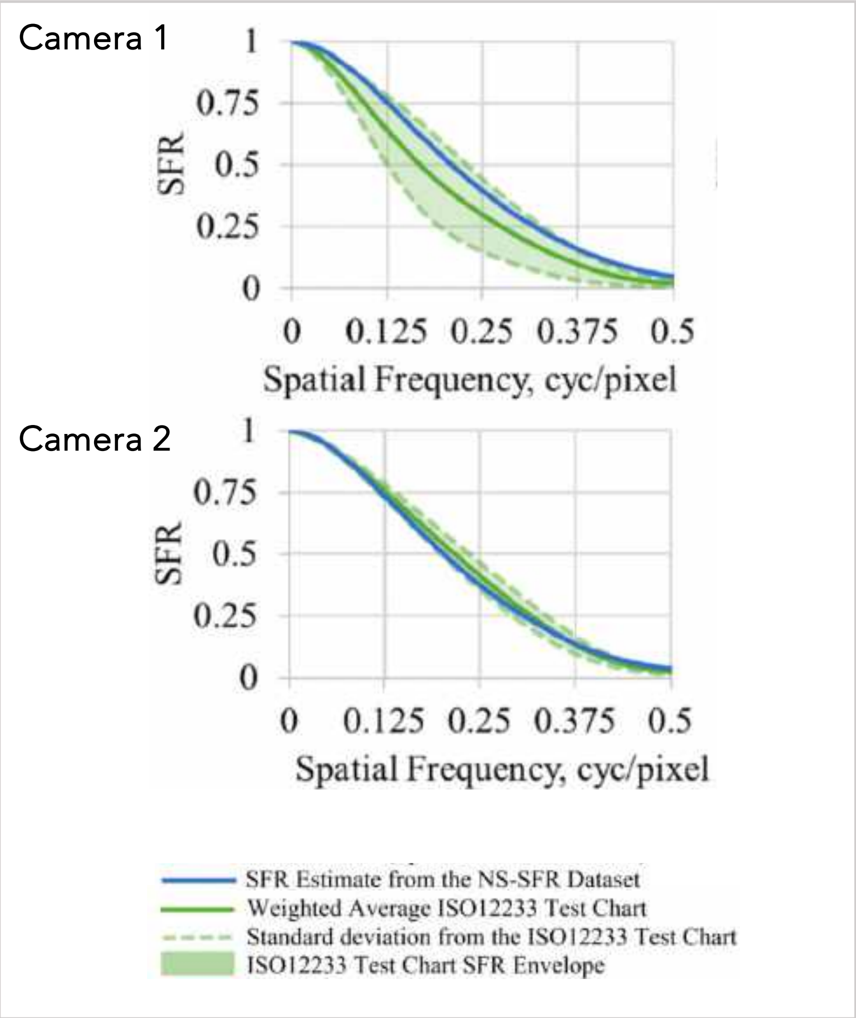
ISO 12233 algorithm

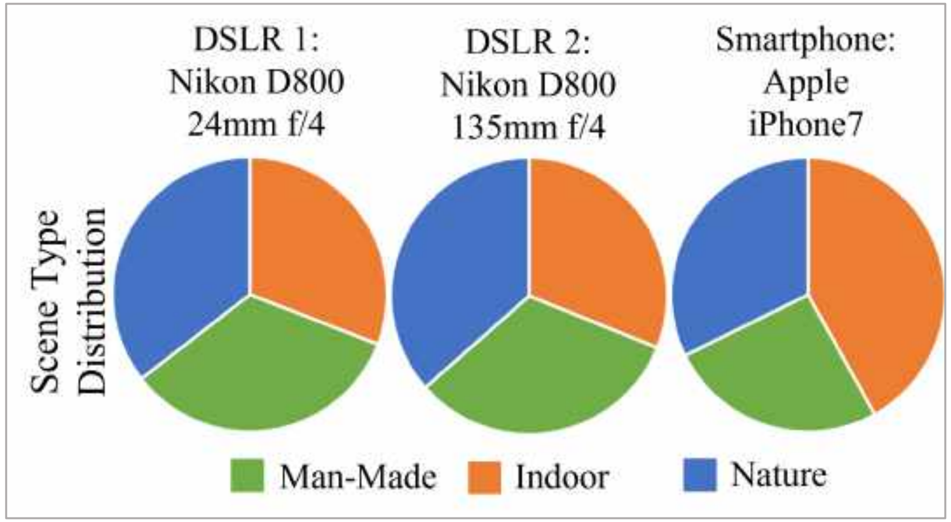
Camera *sharpness* measurement *from natural scenes*



Camera *sharpness* measurement *from natural scenes*

2 x Canon DSLR camera systems (near-linear)

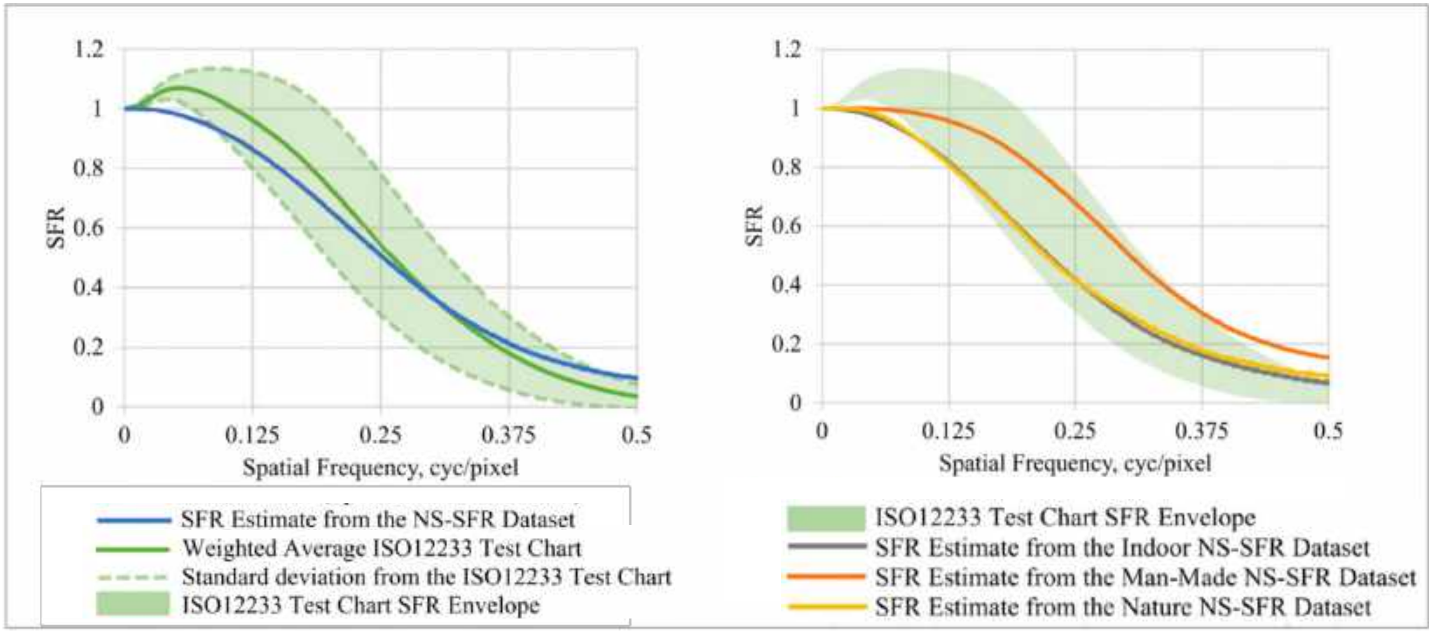


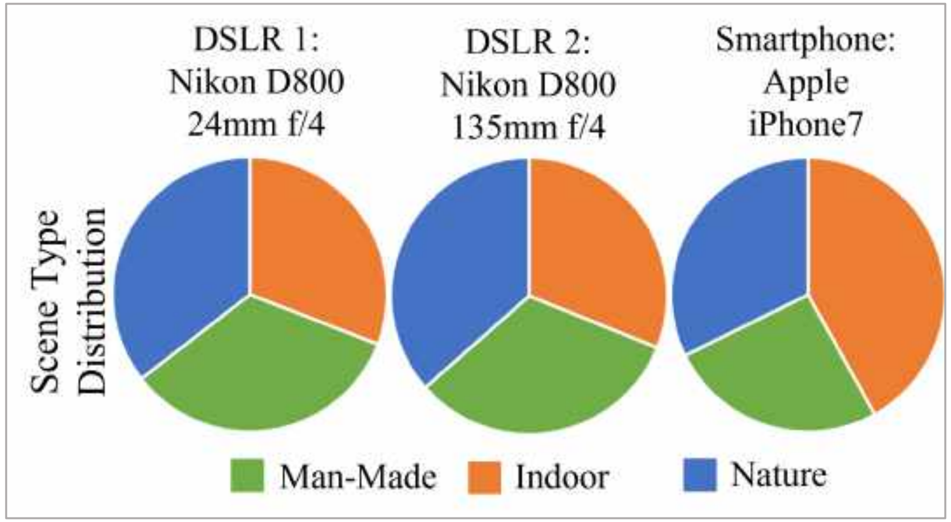


- van Zwanenberg, O., Triantaphillidou, S., Jenkin, R. and Psarrou, A. (2021), *Estimation of ISO12233 Edge Spatial Frequency Response from Natural Scene Derived Step-Edge Data*, JIST, 65 (6), pp. 60402-1-60402-16.
- van Zwanenberg, O., Triantaphillidou, S., Psarrou, A. and Jenkin, R, (2021), *Analysis of Natural Scene Derived Spatial Frequency Responses for Estimating Camera ISO12233 Slanted-edge Performance*, JIST, 65 (6), pp 60405-1 – 60405-12.

Camera *sharpness* measurement *from natural scenes*

iPhone 7 camera system (highly non-linear)





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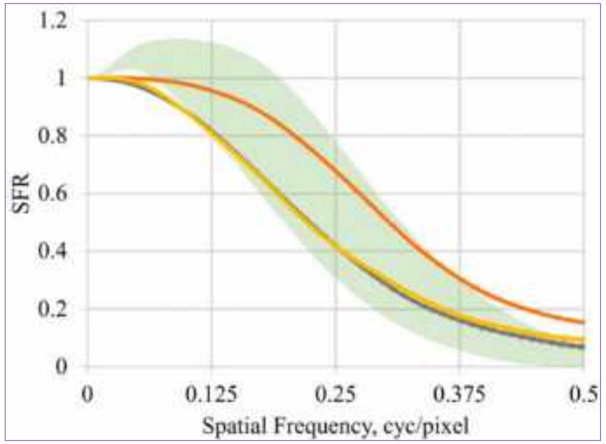
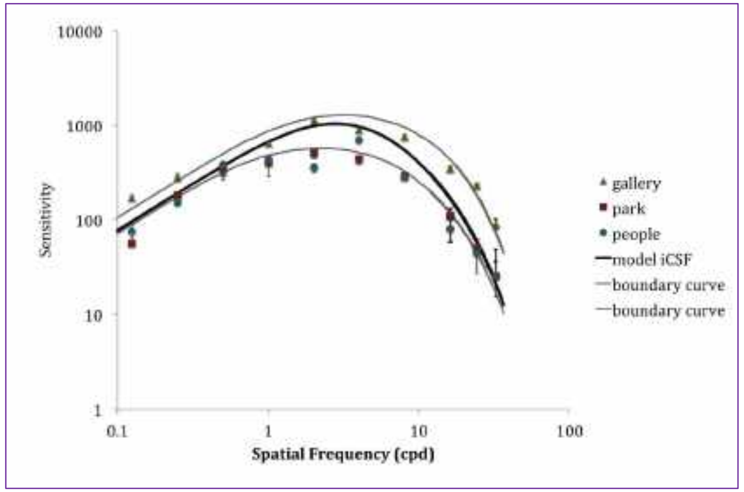
System & scene dependent image quality modelling

Camera ***SFR***(u)



CSF(ν)

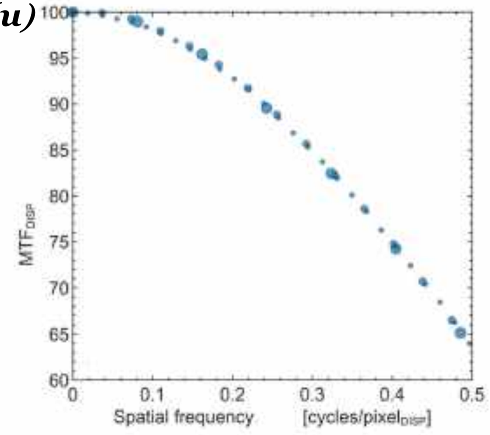


Scene dependent
imaging performance measures

Edge Acutance, ***Q***
(sharpness)
image quality metric

Scene Dependent
visual system models

Display ***M(u)***



Fry, E. W. S., Triantaphillidou, S., Jenkin, R. B., Jacobson, R. E. and Jarvis, J. R. (2019), *Scene-and-Process-Dependent Spatial Image Quality Metrics*, Journal of Imaging Science & Technology, 9, 60407-1-60407-13.

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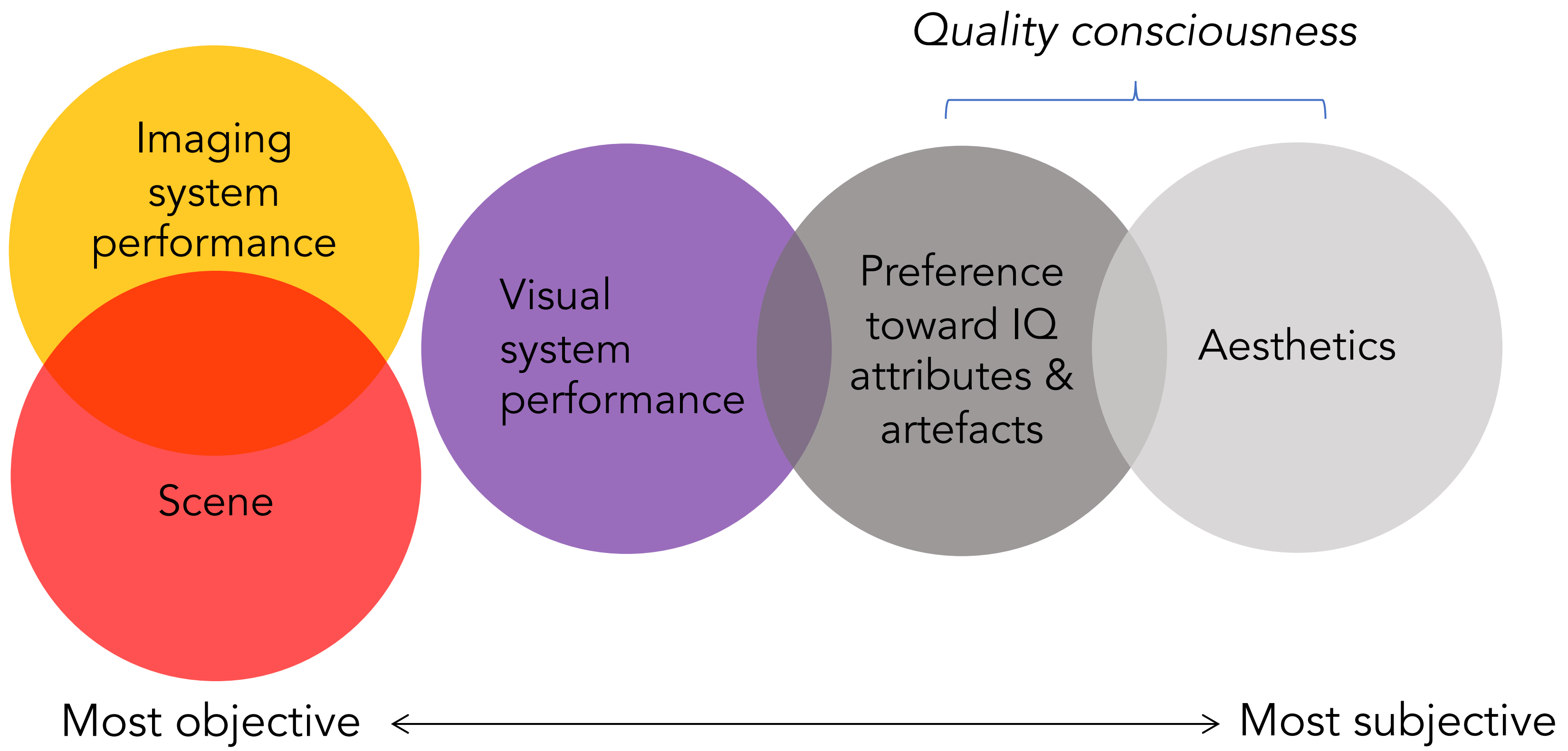
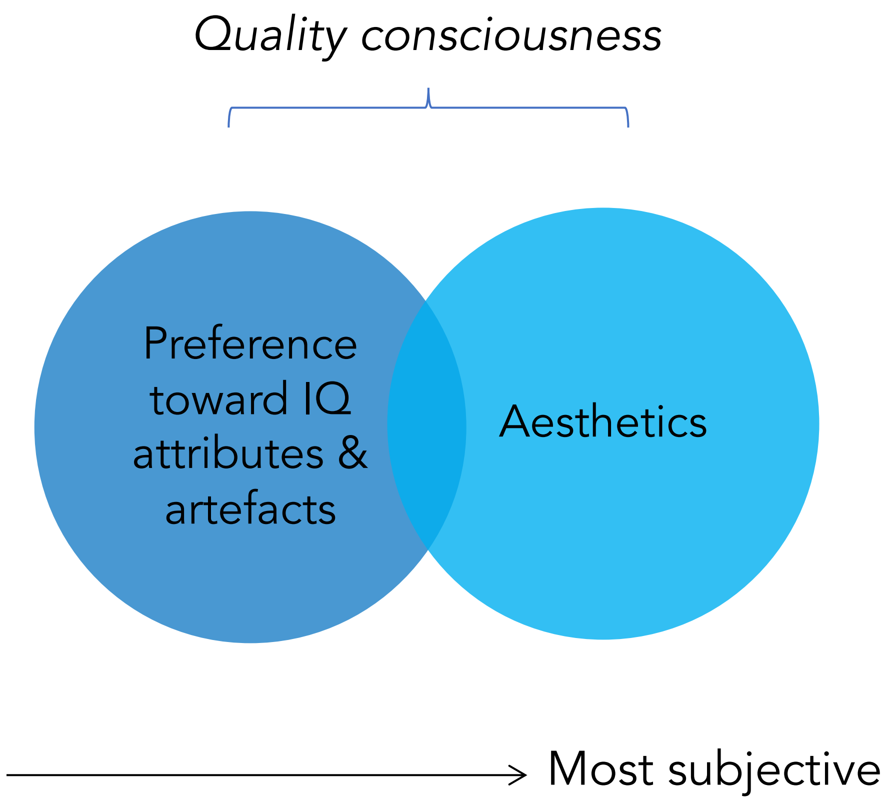


Preference and Aesthetics

- Context dependent
- Culture dependent
- Industry/manufacturer dependent
- Personal
- Change with time
  - Fashion trends
  - Imaging system evolution



Computational aesthetics

" aim to identify or evaluate visual aesthetic expressions in images using algorithms"

- Composition
  - Rule of thirds
  - Golden ratio
  - Focus, focal length, depth of field
- Features
  - Colour
  - Exposure/luminance
  - Edges/textures/sharpness/contrast
- Contents
  - Semantic (high level) information
  - Low level feathers

Evolution of photographic aesthetics

- Analysis of **contemporary** photographic collections to track preference & aesthetics
- Large collections
- Commercial photographic agencies (providing images worldwide)
- 40-50 years period
- Curated image collections (aesthetic value)
- Compare findings with literature (art & science)

SCIENCEphotoLIBRARY IMAGE SOURCE plainpicture

nature picture library Millennium Images

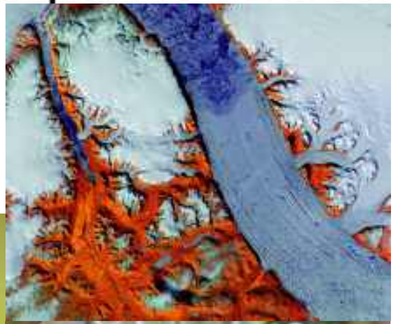
Evolution of photographic aesthetics

A. Nature
   1. Wildlife
   2. Seasonal Landscapes
   3. Underwater Seascapes
   4. Night Sky
   5. Aerial Landscapes
   6. Close-ups

B. People
   1. Portraits (close ups)
   2. Groups of people

C. Satellite

D. Abstracts
   1. Microscopic
   2. Macroscopic
   3. Textures/detail



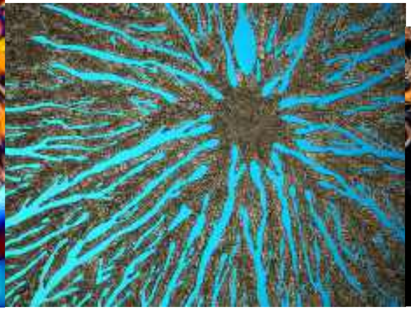












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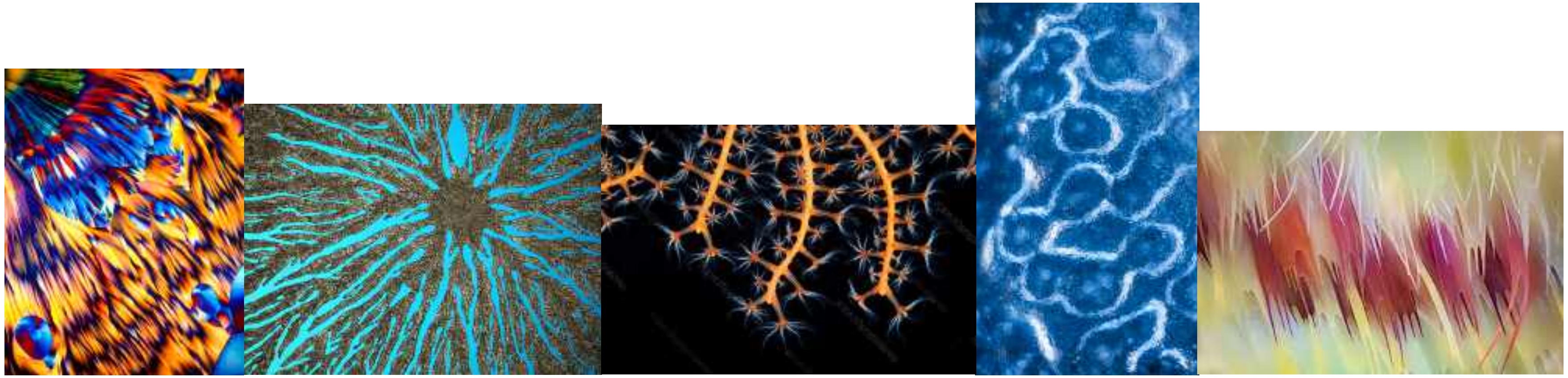

Evolution of photographic aesthetics

Examine color computational aesthetic features

- Colorfulness (CFL) - linear combination of chromaticity variance and chroma magnitude
- Color harmony (CH) - based on the frequency of appearance of color patterns
- Opposing or opponent color (OC)
- Complementary colors (CC)
- Dominant colour palettes (PCP) – based on clustering, and subsequent analysis

Evolution of photographic aesthetics

Discover

- How ”portrait” skin tone rendering varied with time & variation between photo agencies
  - Decade trends
  - Culture trends
  - Effect of medium

Evolution of photographic aesthetics

Discover

- How ”portrait” skin tone rendering varied with time & variation between photo agencies
  - Decade trends
  - Culture trends
  - Effect of medium
- Colour trends in ”abstracts” category – are they identified, any discoveries?
  - Balance
  - Rhythm/pattern
  - Variety
  - Contrast
  - Movement
  - Surprise

Evolution of photographic aesthetics

Further work

- Most (all) categories
- Attributes
    - image complexity
    - rule of thirds
    - golden ratio
    - diagonal and leading lines
    - focus and depth of field

Evolution of photographic aesthetics

Further work

- Most (all) categories
- Attributes
  - image complexity
  - rule of thirds
  - golden ratio
  - diagonal and leading lines
  - focus and depth of field
- Hand crafted features and potential AI tools
- Compare computational findings with literature findings on photo aesthetics

Summary

- **Image quality evaluation** involves understanding scene contents, imaging systems, human vision and cognition
- Image quality modelling, viewed from an **engineering** viewpoint, requires investigation of all abovementioned elements and their interrelationships
- Developed scene-and-system-dependent camera **performance measures** (sharpness & noise) and tested it with different camera systems (linear **DSLR** and non-linear content aware **iphone** cameras) - eliminating test chats.

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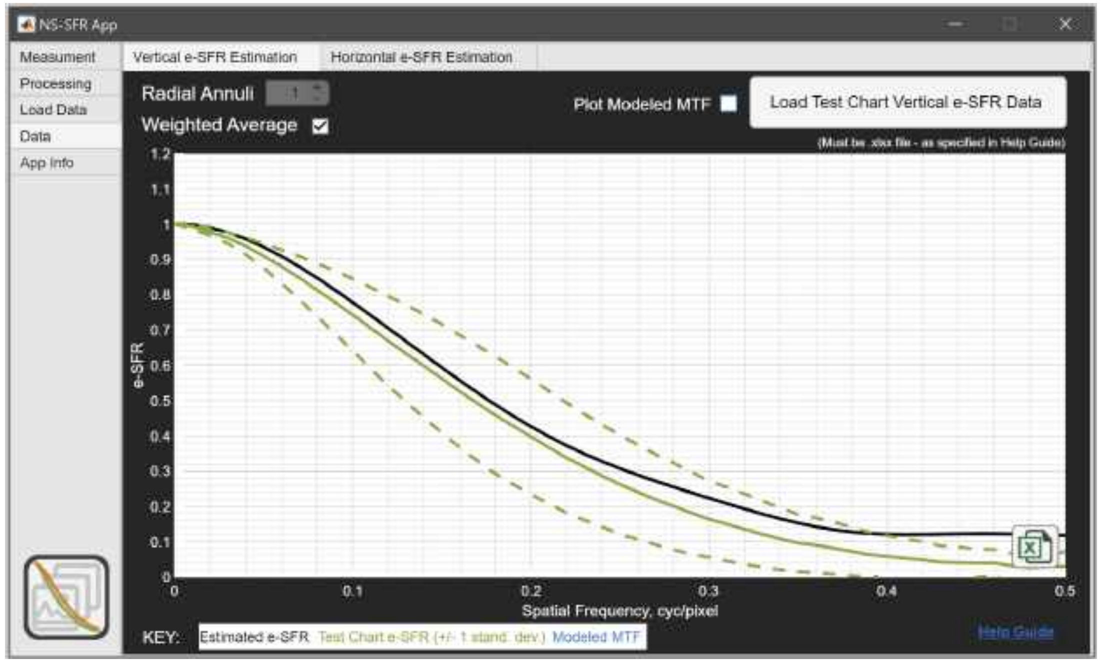
- Moving from scene-dependent imaging performance modelling to modelling preference and aesthetics bridges a gap
- Track aesthetics in contemporary photography using computational means and photo collections with known aesthetic values

GUI for NS-SFR measurement and e-SFR estimation



van Zwanenberg, O., Triantaphillidou, S. and Jenkin, R. (2023), *A tool for deriving camera spatial frequency response from natural scenes (NS-SFR)*, IS&T Electronic Imaging Symposium: Image Quality & System Performance conference XX, San Francisco, California, USA.

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Thank you

- van Zwanenberg, O., Triantaphillidou, S. and Jenkin, R. (2023), *A tool for deriving camera spatial frequency response from natural scenes (NS-SFR)*, IS&T Electronic Imaging Symposium: Image Quality & System Performance conference XX, San Francisco, California, USA.
- Jarvis, J., Triantaphillidou, S. and Gupta, G. (2022), *Contrast discrimination in images of natural scenes*, Journal of the Optical Society of America A. 39 (6), pp. B50-B64.
- van Zwanenberg, O., Triantaphillidou, S., Jenkin, R. and Psarrou, A. (2021), *Estimation of ISO12233 Edge Spatial Frequency Response from Natural Scene Derived Step-Edge Data*, Journal of Imaging Science and Technology, 65 (6), pp. 60402-1-60402-16.
- van Zwanenberg, O., Triantaphillidou, S., Psarrou, A. and Jenkin, R, (2021), *Analysis of Natural Scene Derived Spatial Frequency Responses for Estimating Camera ISO12233 Slanted-edge Performance*, Journal of Imaging Science and Technology, 65 (6), pp 60405-1 – 60405-12.
- van Zwanenberg, O., Triantaphillidou, S., Jenkin, R. and Psarrou, A. (2021), *Natural Scene Derived Camera Edge Spatial Frequency Response for Autonomous Vision Systems*, IS&T London Imaging Meeting 2021.
- van Zwanenberg, O., Triantaphillidou, S., Jenkin, R. and Psarrou, A. (2020), *Camera System Performance Derived from Natural Sciences*, IS&T Electronic Imaging Symposium: Image Quality & System Performance conference, San Francisco, California, USA. (Best conference paper award)
- Fry, E. W. S., Triantaphillidou, S., Jenkin, R. B., Jacobson, R. E. and Jarvis, J. R. (2020), *Noise Power Spectrum Scene-Dependency in Simulated Image Capture Systems*, In: IS&T Electronic Imaging Symposium: Image Quality & System Performance conference, San Francisco, California, USA.
- Fry, E. W. S., Triantaphillidou, S., Jenkin, R. B., Jacobson, R. E. and Jarvis, J. R. (2019), *Scene-and-Process-Dependent Spatial Image Quality Metrics*, Journal of Imaging Science & Technology, 9, 60407-1-60407-13.
- Fry, E. W. S., Triantaphillidou, S., Jenkin, R. B., Jacobson, R. E. and Jarvis, J. R. (2019), *Validation of Modulation Transfer Functions and Noise Power Spectra from natural scenes*, Journal of Imaging Science & Technology, 9, 60406-1-60406-11.
- Van Zwanenberg, O., Triantaphillidou, S., Jenkin, R. and Psarrou, A. (2019), *Edge detection techniques for quantifying spatial imaging system performance and image quality*, ACM/IEEE Conference on Computer Vision and Pattern Recognition (IEEE/ CFV CVPR 2019). Long Beach, California 15 – 21 Jun 2019.
- Triantaphillidou, S., Jarvis, J. R., Psarrou, A. and Gupta, G. (2019) *Contrast sensitivity in images of natural scenes*, Signal Process Image, Signal Processing: Image Communication, 75, pp. 64-75.
- Fry, E., Triantaphillidou, S., Jacobson, R., Jarvis, J. and Jenkin, R. B. (2018), *Bridging the Gap Between Imaging Performance and Image Quality Measures*. In: IS&T Electronic Imaging Symposium 2018 – Image Quality System Performance XV, San Francisco, CA, USA. (Best student paper award)