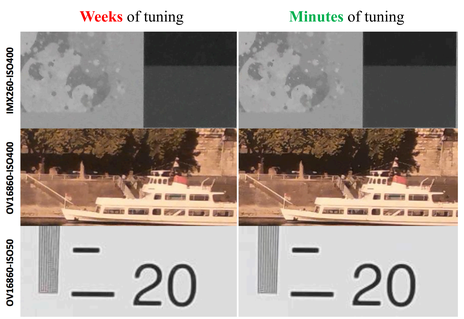
# AUTOMATIC ISP IMAGE QUALITY TUNING USING NON-LINEAR OPTIMIZATION

Jun Nishimura, Timo Gerasimow, Sushma Rao, Aleksandar Sutic, Chyuan-Tyng Wu, Gilad Michael

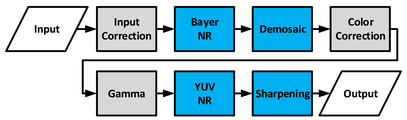
Intel Corporation, Santa Clara, USA

## Introduction




*Comparison between "Hand-tuned' and 'Auto-tuned' images on IMX260 and OV16860.*

- A typical, modern ISP has multiple processing blocks that include complex image processing algorithms, such as noise reduction (NR), demosaicing and sharpening
- The effort of manual image quality (IQ) tuning is extremely high due to ISP block inter-dependencies, large number of high level tuning parameters and thorough review of the image quality
- Combining non-linear optimization with automatic reference image generation produces highly competitive results in minutes whereas manual tuning by IQ experts takes weeks



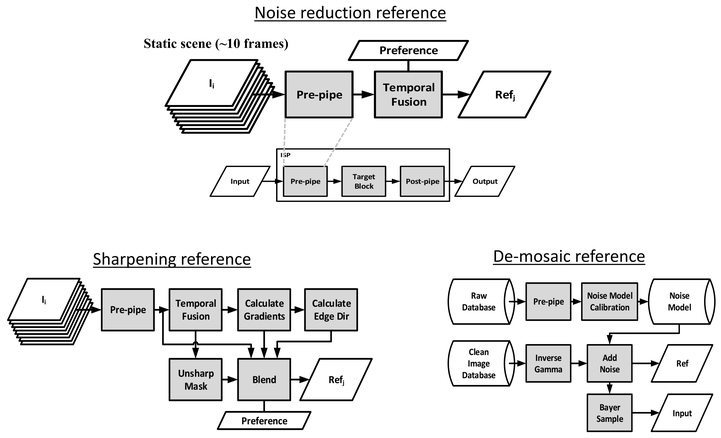

*Basic ISP pipeline*

## Key contributions

- Prior work: Conducted experiments with IQ KPIs (e.g. SNR and texture acutance) using MOEA/D. Results indicate that IQ KPIs do not impose enough constraints on image quality artifacts as it is possible to achieve good IQ KPIs even in the presence of unacceptable artifacts.
- Automatic reference image generation method that outputs superior quality in all IQ aspects with respect to the ISPs real-time capabilities
- Non-linear, gradient-free optimization that can solve non-convex problems: Combination of global and local optimization produces repeatable results that are highly competitive against hand-tuned IQ

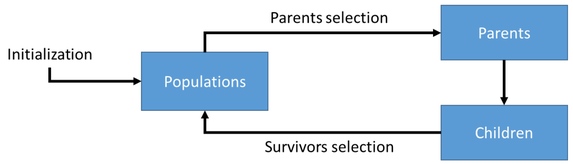


## Reference Image Generation




### Global optimization: Artificial Bee Colony

*Generate and explore new set of tuning points*

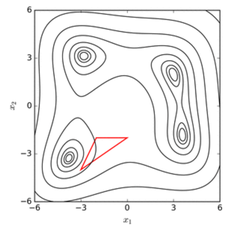



### Local optimization: Subplex, Nelder-Mead simplex

*Refine towards optimal solution (gradient approximation)*

**Subplex Algorithm**

Initialize with **global optimization result** or
Initialize with **tuning result from lower sensor gain**
for regularization
while Termination-criteria not met
  Set step size and subspaces
  for each subspace
    n ← subspace dimension
    do **Nelder-Mead Simplex** method
      Create an initial simplex with n + 1 points
      *Y* consist of $n + 1$ linearly independent points
      while Termination-criteria not met
        $x_k \leftarrow \text{argmax } f(x_i), x_i \in Y$
        $\bar{x} \leftarrow \frac{1}{n+1}\sum_{i \in Y \setminus \{x_k\}} x_i$
        $\Delta x \leftarrow x_k - \bar{x}$
        Replace $x_k$ in Y by $x_k^+ \leftarrow \bar{x} + \Delta x$






## Experiments

| | Portraits A | Portraits D54 | Studio |
|---|---|---|---|
| IQ expert 1 | A | A | D |
| IQ expert 2 | A | A | A |
| IQ expert 3 | A | A | E |
| IQ expert 4 | A | A | A |
| IQ expert 5 | A | A | A |
| IQ expert 6 | A | A | E |

*Results of an IQ assessment, conducted as blind experiment: Each participating image quality expert were shown five images of each of the three scenes (Portraits A and D54, and Studio) and were asked to select the best one in terms of IQ. Images were labeled as A, B, C, D and E, where images labeled with 'B' were hand-tuned manually and all other images were auto-tuned.*

| | MAD | | | SSIM | | | MS-SSIM | | |
|---|---|---|---|---|---|---|---|---|---|
| | Not | Hand | Auto | Not | Hand | Auto | Not | Hand | Auto |
| Bayer NR | 1.7507 | 1.1998 | **1.1618** | 0.8607 | 0.9313 | **0.9357** | 0.9062 | 0.9401 | **0.9421** |
| Demosaic | 11.7463 | 11.3349 | **10.4392** | 0.8968 | 0.9100 | **0.9237** | 0.9728 | 0.9775 | **0.9794** |
| Sharpening | 3.1719 | 1.6488 | **1.4921** | 0.9557 | 0.9822 | **0.9848** | 0.9834 | 0.9958 | **0.9969** |
| YUV-NR | 0.8788 | 0.8781 | **0.8554** | 0.9934 | 0.9952 | **0.9970** | 0.9945 | 0.9961 | **0.9971** |

*Difference between reference and each tuning output for each key ISP block: results are shown for not-tuned, hand-tuned and auto-tuned images.*

## Live demonstration