REDUCING NUMBER OF MEASURING POINTS FOR ESTIMATING SPECTRUM OF COLORIMETRIC PROBE

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ABSTRACT: As the world of IoT, and sensor-data gathering is becoming more widespread, reducing the cost of each sensor system is becoming an important factor. In this paper reducing the number of necessary measuring points for estimating a reflected electromagnetic spectrum is presented. In our previous work, a machine learning-based method was proven to be superior to Cubic Hermite interpolation in estimating spectrum based on six measured values.
Now the new hypothesis is that the number of measuring points could be decreased without the significant loss of the spectrum estimation. Another goal of this paper is to determine the quality of estimated spectrum, using our method, based on measures from only Red, Green and Blue diodes, which are widely available.
In order to train the network, a dataset was needed. The ECI2002 test chart (Fig. 2) was used to create the dataset, which was further divided into training and test subset. For all the colors on the test chart, the measurements were performed with the device proposed in our previous work, as well as with the commercial spectrophotometer XRite i1 Publish Pro2, which were then used as the ground truth, or refference values.

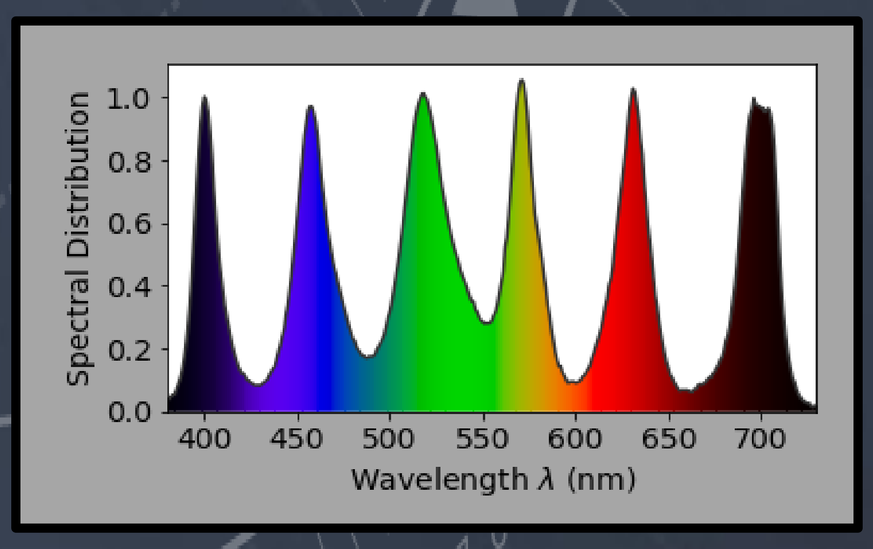

Fig. 1 Measuring points diode wavelengths

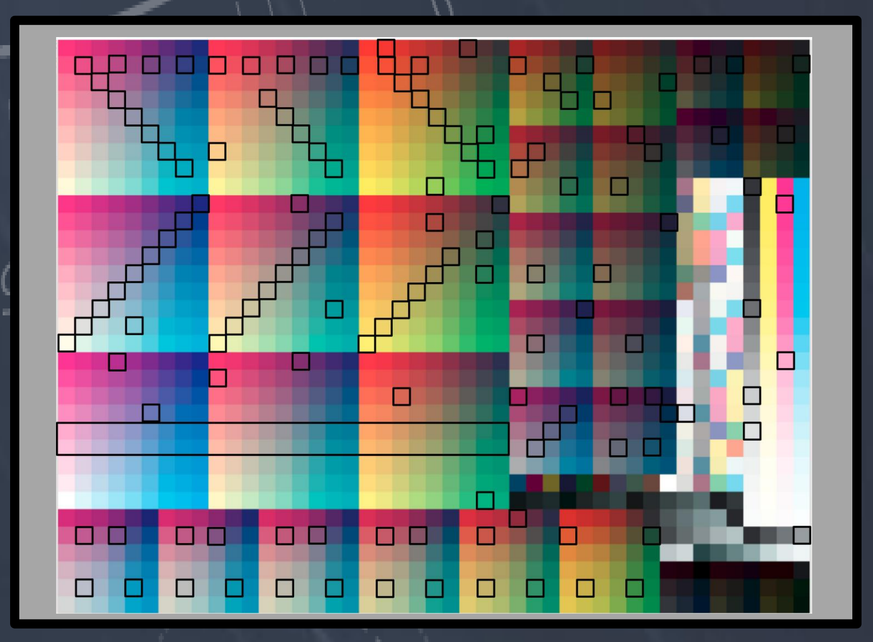

Fig. 2 ECI2002 test chart

METHODOLOGY: There are total of six measuring points aquired using six diodes of different wavelengths (Fig. 1) and one broadband detector.
The diodes are at 400 nm, 457 nm, 517 nm, 572 nm, 632 nm and 700 nm.
The idea is to use subset of measured values and train Artificial neural network to estimate spectrum based on those measures, the goal is to determine how much the reduction of input values affects the estimated spectrum.

Proposed combinations:
1. All of the measuring points
2. Five measuring points – without the diode on 400 nm
3. Four measuring points – without the diodes on 400 and 700 nm
4. Three measuring points – using RGB diodes

For each combination, the ANN would be trained to estimate spectrum using specific measured values for inputs and ground truth from commercial spectrophotometer as output. The quality of neural network output spectrum would be estimated using ΔE_{00} (CIE2000) metric.

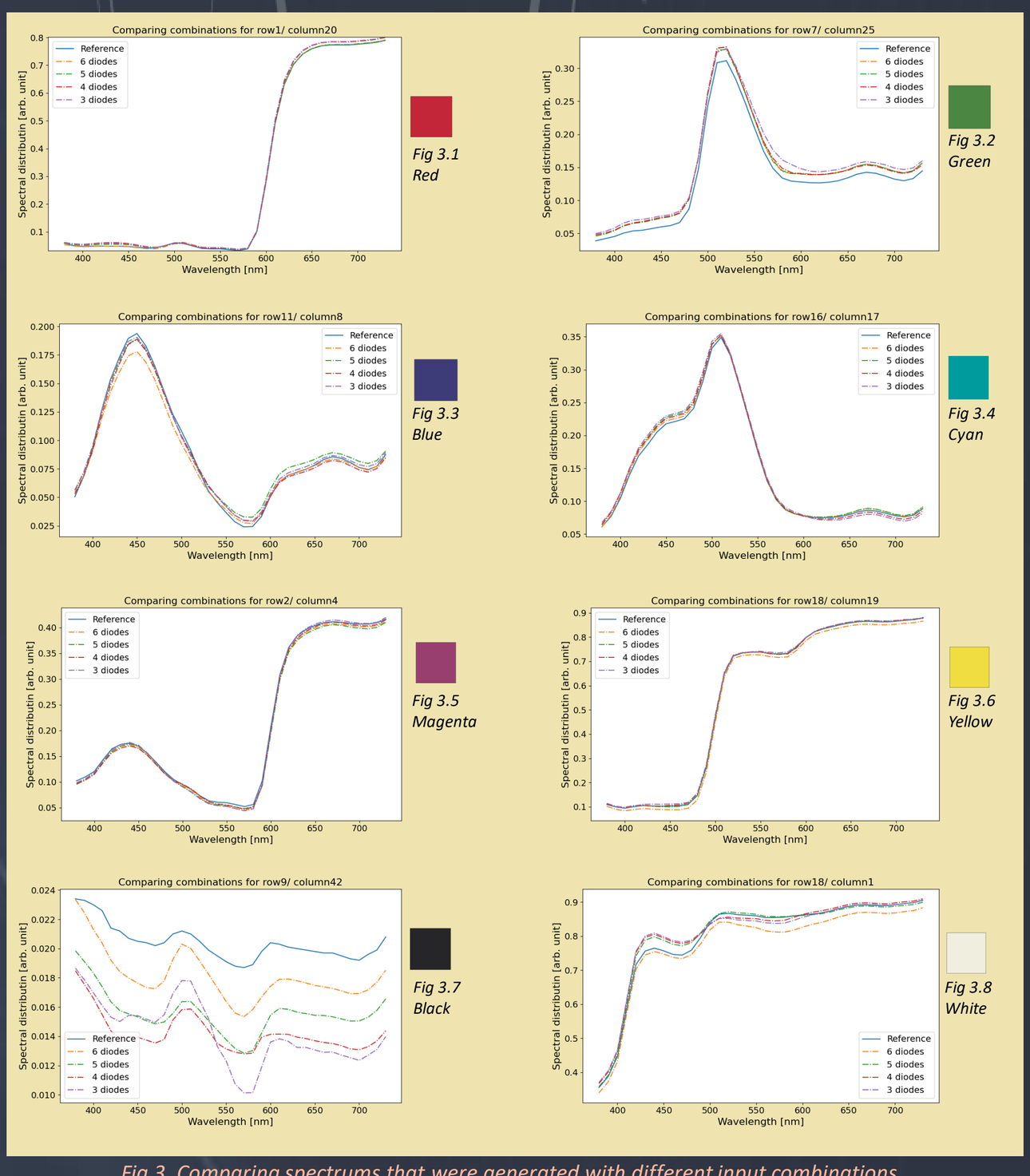

Fig 3.1 Red
Fig 3.2 Green
Fig 3.3 Blue
Fig 3.4 Cyan
Fig 3.5 Magenta
Fig 3.6 Yellow
Fig 3.7 Black
Fig 3.8 White

Fig 3. Comparing spectrums that were generated with different input combinations for different colors

	Red	Green	Blue	Cyan	Magenta	Yellow	Black	White
6 diodes ΔE	0.85	1.83	1.32	0.49	1.02	0.75	0.75	1.48
5 diodes ΔE	0.82	1.76	1.68	1.05	1.08	0.11	0.11	1.47
4 diodes ΔE	1.84	1.92	1.15	0.80	0.54	0.23	0.23	3.18
3 diodes ΔE	1.16	2.58	0.89	1.04	1.31	0.40	0.40	3.66

Table. 1 ΔE_{00} for different colors

	Average ΔE	Max ΔE	Min ΔE
6 diodes	**1.37**	4.36	0.16
5 diodes	**1.47**	4.7	0.11
4 diodes	**1.59**	4.56	0.22
(RGB) 3 diodes	**1.79**	5.7	0.14

Table. 2 Average, maximal and minimal ΔE_{00} for different combinations (whole test set)

CONCLUSION: In this paper, the analysis of reducing the number of measuring points, while maintaining low ΔE_{00} is presented.

The hypothesis that, by reducing the number of measurement points the ΔE_{00} increases, is proven to be correct. The total average ΔE on all test cases went from 1.37 to 1.79 (Table 2).
However, average of dominately yellow colors, for example, is not affected much by reducing the measuring points, while the dominately bright colours have more than double the ΔE with three measurement points opposed to six.

Maximal ΔE increased also, and by reaching value over five for three measurement points, the estimated spectrum is different enough that even untrained eye could see.

The minimal ΔE seems not to depend much on the number of measured points. Values are small and perhaps some measurement noise or even the initial conditions at the beginning of the training influence this more that number of diodes used.