Functional spectral filter optically simulating colour discrimination property of dichromats

Kanae MIYAZAWA**, Tatsuya ONOUCHI**, Hirofumi ODA**, Keiyo SHINOMORI***, Shigeki NAKAUCHI**

**Itoh Optical Industrial Co., Ltd., JAPAN
***Department of Information & Computer Sciences, Toyohashi University of Technology, JAPAN
****Department of Information Systems Engineering, Kochi University of Technology, JAPAN
(k-miyazawa, h-oda)@itohopt.co.jp, shinomori.keiyo@kochi-tech.ac.jp, naka@bpel.ics.tut.ac.jp

Background and Purpose
Colour universal design
For universal access, confusing colour combinations should be avoided in documents for colour vision deficiency (CVD).

Earthquake hazard maps of Toyahashi city, Japan: (a) Old map with confusing colour combinations and (b) New map without these under colour universal design.

Such confusing colour combinations may be avoided by using:
- a special kind of software (e.g. Vischeck) or
- a chart with hundreds of colour combinations
However, these are some problems with these previous methods.

Proposed method
Just Seeing with a Filter
Our goal is to make a functional spectral filter so that users with normal colour vision can easily find the confusing colour combinations for dichromats.

Spectral Filter Design
In its severe forms, colour deficiency is caused by absence of one (or more) of the cone visual pigments.
However...
It is theoretically impossible to reduce the spectral sensitivity of only one type of cones by filtering.

Filter design policy
Spectral transmittance of the filter was designed so that the magnitude of colour differences for a normal observer with the filter would be close to those for colour dichromats.

How to design the filter
The design process of the filter was formulated as the optimization in order to minimize the discrepancy in colour differences between people in normal vision with the filter and dichromats.

Optimization
1. Definition of the viewing condition, CIE diffuse light, Standard (D-65), CIE illuminant
2. Definition of parameters for the filter, wavelength, width, height, etc.
3. Calculation of colour appearance by the simulation (e.g., "CIE 2000")
4. Calculation of the colour differences between 16 patches
5. Calculation of the evaluation function, E

Development of the optical filter by vacuum deposition technology
Multi-layer thin-film technology
The spectral filter designed theoretically was developed by vacuum deposition technology. First, the thickness in each layer was decided by multi-layer thin-film design software. Then, the thin-film was realized by a vacuum deposition system.

Evaluation
Evaluation results of the optical filter
The results of tests with Ishihara plates and Panel D-15 test indicated that colour-normal observers with the filter are approximately identical to dichromats (more like proton) in terms of their colour discrimination.

Examples
- photos taken by a camera without/with the filter

Conclusion
The results demonstrate that colour discrimination for the users with the filter falls between protonates and deutanopes, meaning that the filter can be reasonably used for colour universal design. In addition, we have already confirmed that proton-type and deutan-type filters can be made theoretically using the same design method.