Functional spectral filter optically simulating colour discrimination property of dichromats

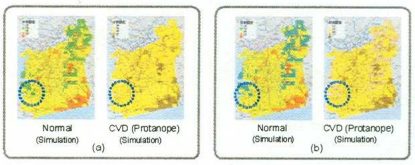
Kanae MIYAZAWA*, **, Tatsuya ONOUCHI**, Hirofumi ODA*, Keizo SHINOMORI***, Shigeki NAKAUCHI**

*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.keizo@kochi-tech.ac.jp, naka@bpel.ics.tut.ac.jp

Background and Purpose

Colour universal design

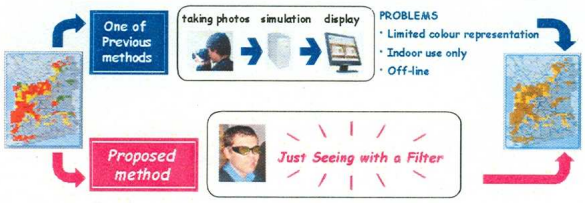
For universal access, "confusing colour combinations" should be avoided in documents for colour vision deficiency (CVD)



Earthquake hazard maps of Toyohashi city, Japan; (a) Old map with confusing colour combinations and (b) New map without them 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

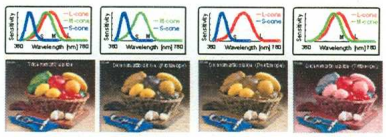
However, there are some problems with these previous methods



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

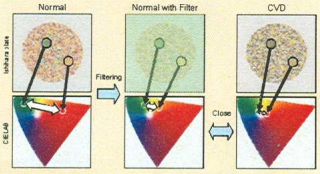
In its severe forms, colour deficiency is caused by absence of one (or more) of the cone visual pigments.



However....
it is **theoretically impossible** to reduce the spectral sensitivity of **only one type of cones** by filtering.

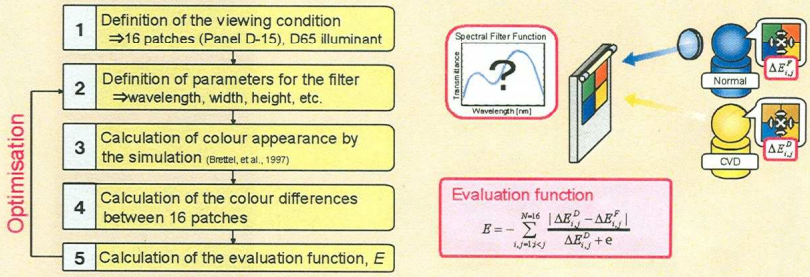
Filter design policy

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

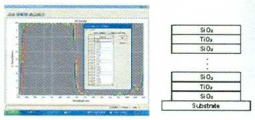
The design process of the filter was **formulated as the optimisation** in order to minimise the discrepancy in colour differences between people in normal vision with the filter and dichromats.



Development of the optical filter by vacuum deposition technology

Multilayer thin-film technology

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



Thickness in each layer was decided

Vacuum deposition system and lens holder

Optical filter, for glasses and video cameras

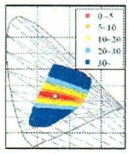
Evaluation

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 protan) in terms of their colour discrimination.

		Normal with filter		
		ΔE<5	ΔE>=10	
Protan OR Deutan	ΔE<5	6.58	4.26	Miss 5.92%
	ΔE>=10	0.00	67.80	FA 0.00%
				F-value 98.95%

※ "Miss" = P(ΔE<5 for CVD | ΔE>=10 for with-filter)
"False Alarm (FA)" = P(ΔE<5 for with-filter | ΔE >= 10 for CVD)



Ishihara Plates

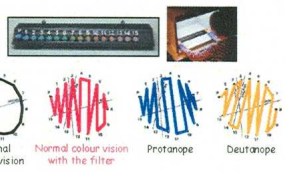
Normal colour vision with the filter

without the filter (6) with the filter (5)

photos taken by a camera without/with the filter

Ishihara plates for colour-normal observers with the filter (N=88). Result error scores of all observers were similar to dichromats. (Average error for 9 plates: 0.0 → 6.42)

Panel D-15 test



The results of Panel D-15 test for colour-normal observers with the filter are similar to dichromats (between results of protanope and deutanope).

Examples

- photos taken by a camera without/with the filter

Station map

without the filter **with the filter**

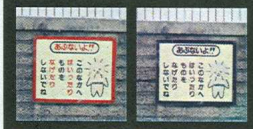
Car parking information

without the filter **with the filter**

Drink in a vending machine

without the filter **with the filter**

Warning for children



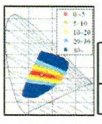
without the filter **with the filter**

Information board at railway station

without the filter **with the filter**

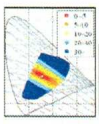
Conclusion

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



Protan type

		Normal with filter		
		ΔE<5	ΔE>=10	
Protan	ΔE<5	5.83	0.00	Miss 0.00%
	ΔE>=10	0.00	77.23	FA 0.00%
				F-value 100.00%



Deutan type

		Normal with filter		
		ΔE<5	ΔE>=10	
Deutan	ΔE<5	5.71	0.00	Miss 0.00%
	ΔE>=10	0.00	74.26	FA 0.00%
				F-value 100.00%

Acknowledgement: This work was supported by the Regional New Consortium Projects from the Ministry of Economy, Trade and Industry of Japan (17C4020)