



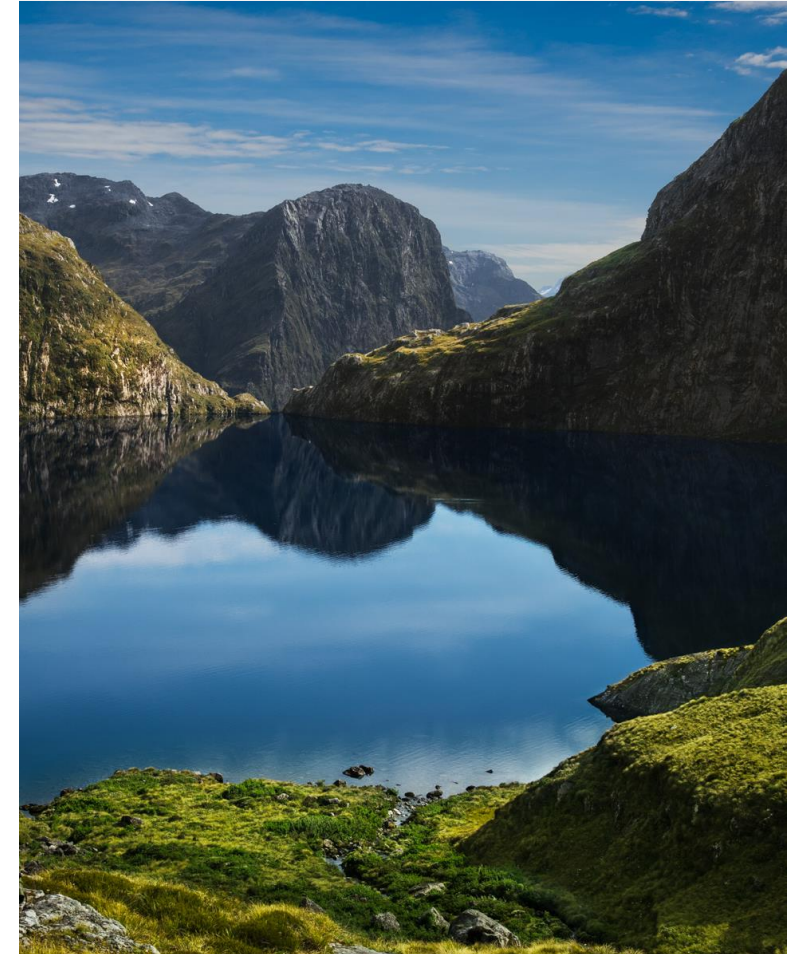
Defining a colour perception threshold for the use of colour in aircrew helmet mounted displays

Dr James Sadler, QinetiQ, UK
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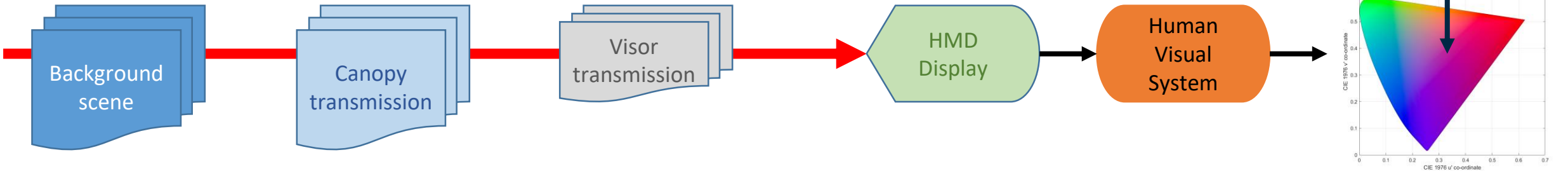
Overview

- Aircrew Head Mounted Displays (HMDs) have evolved.
 - Legacy HMDs based upon miniature Cathode Ray Tube (CRT) technology providing green symbology (P43 phosphor).
 - Latest systems offer ability to display high luminance colour symbology at high resolution.
- Ability to see symbology is dependent upon differences in luminance and chromaticity relative to the background scene.
 - Luminance contrast 
 - Chromatic contrast 
- Operational environment is not limited to blue sky flying above the clouds:
 - Desert, grassland, woodland, mountains, urban (concrete, tarmac);
 - Sea, lakes, snow;
 - Overcast sky, blue sky, sunlit cloud.
- HMDs are used on different platforms, with different canopy transmission properties.
 - Modelling should allow for this variable.



Approach

This model and the approach are based on well defined and validated theories of colour vision and physics of light transmission.



Air to ground

- Woodland
- Desert
- Sea
- Concrete/Tarmac

Air to air

- Cloudy sky
- Blue sky

Platform

- Fast Jet
- Rotary Wing
- Multi-engine

Helmet visors

- Dark visor
- Clear visor with contrast enhancement patches

Display

- Assumed to be capable of generating any colour of symbology at a given luminance.

Contrast

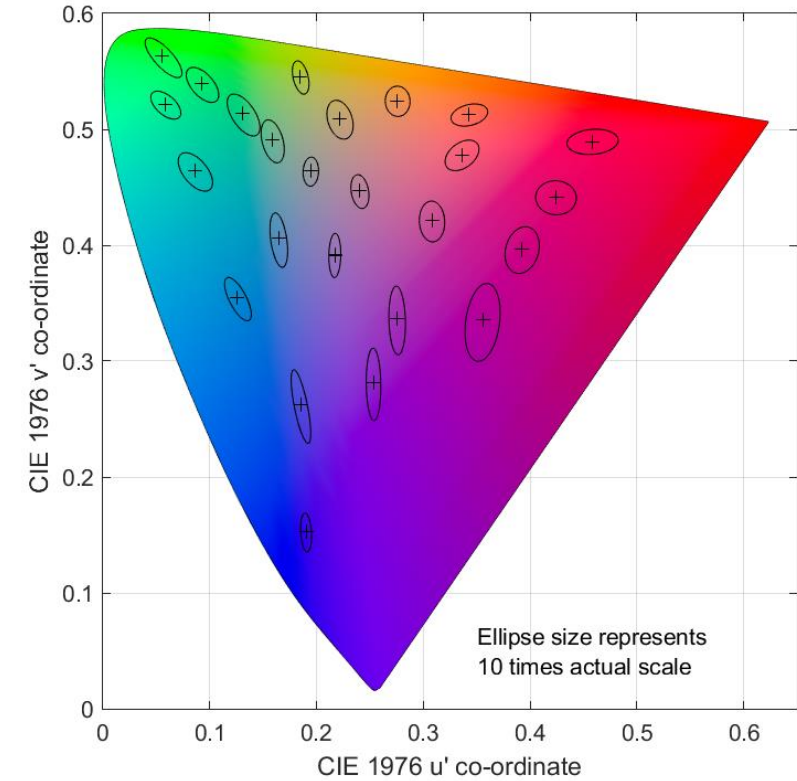
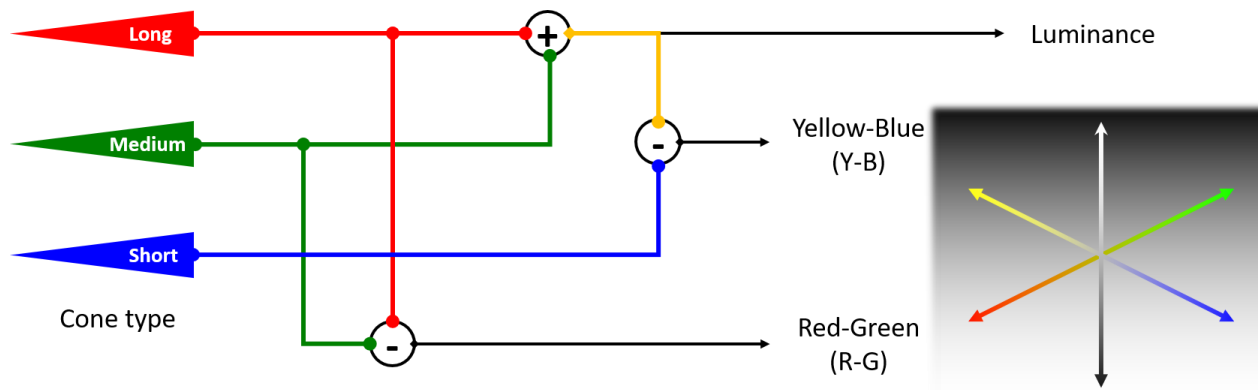
- Luminance
- Chromatic

Commission

- Internationale de l'Eclairage (CIE) plot
- 1976 CIE LUV (u' , v')

Visual function

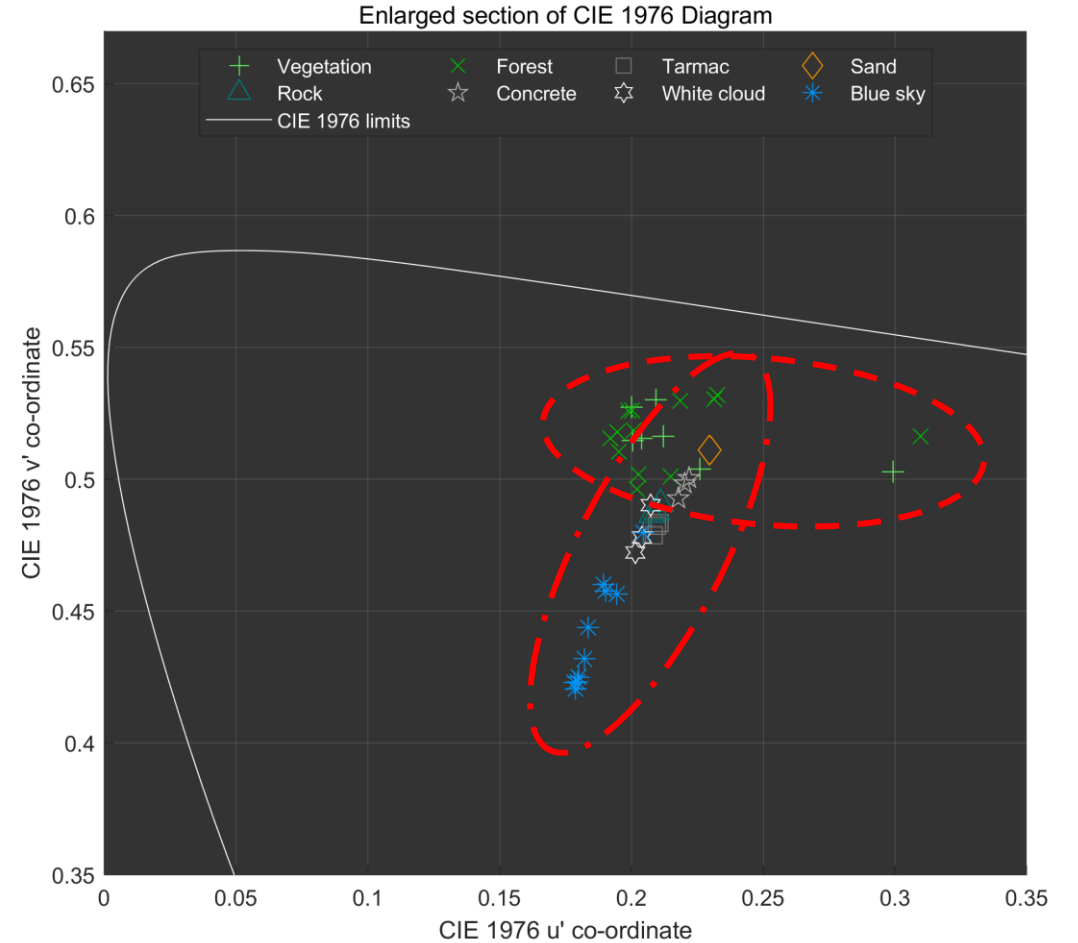
- Daytime, or photopic, vision is primarily mediated by the cone photoreceptors in the eye.
- There are three cone types whose signals combine to give the perception of colour and luminance.
- The assimilation of spatial cues is derived from luminance contrast.
- Colour can facilitate differentiation of an object from its surroundings and play a role in visual search.



Colour can be specified in terms of a co-ordinate frame defined by the CIE.

Model backgrounds

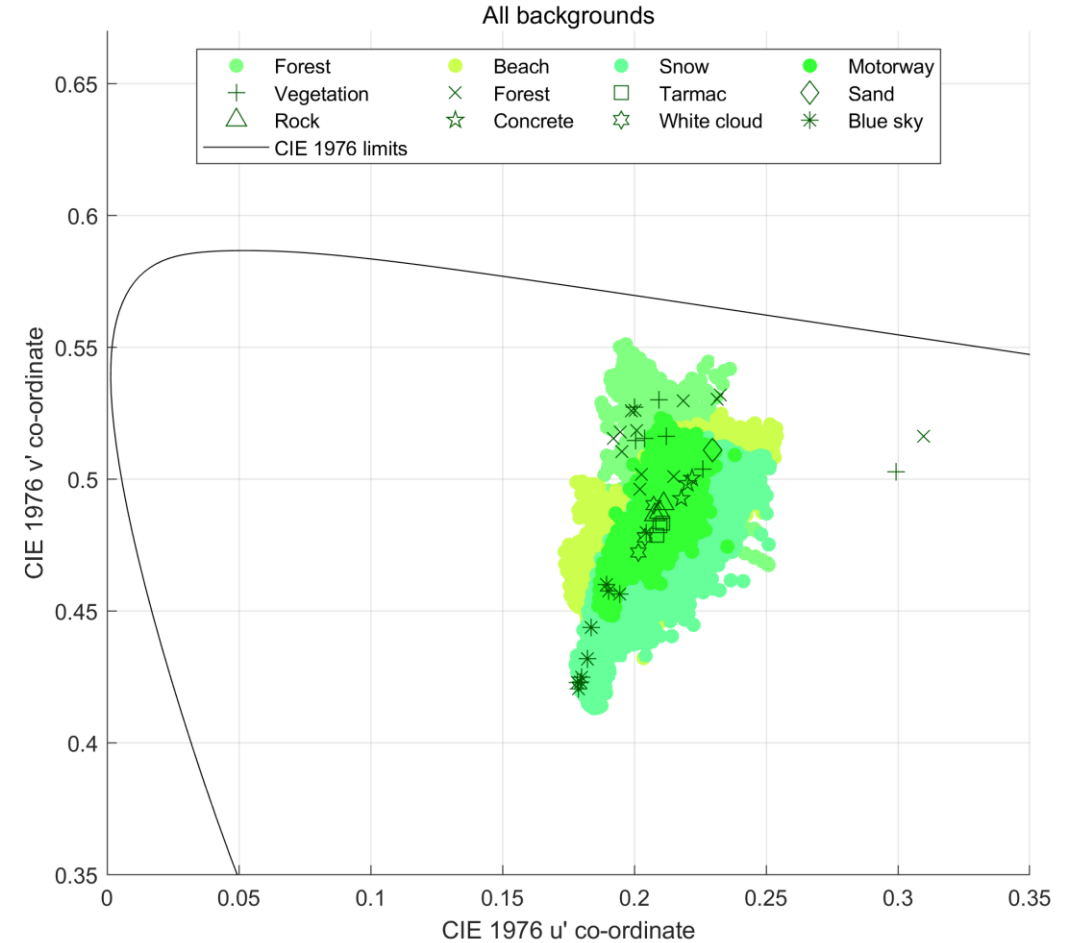
A set of backgrounds were defined based upon operational scenarios applicable to aircrew of fixed and rotary wing military aircraft.



Model backgrounds

A set of backgrounds were defined based upon operational scenarios applicable to aircrew of fixed and rotary wing military aircraft.

This set of backgrounds are comparable to data from a larger set of background data (Parraga et al, 2020).

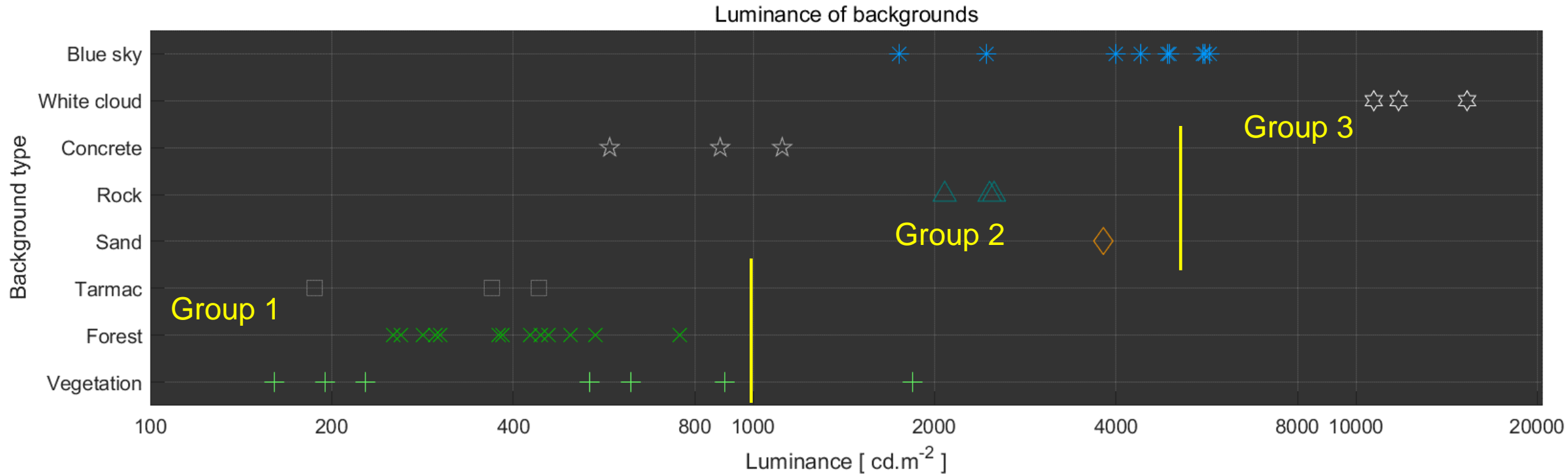


*Parraga et al, Accurate mapping of natural scenes radiance to cone activation space: a new image dataset, Colour in Graphics, Imaging Vision 2020

Model backgrounds

Backgrounds split into three sets based upon their luminance.

- Group 1 = {forest, vegetation, tarmac}
- Group 2 = {concrete, sea, sand, rock}
- Group 3 = {blue sky, cloud}



Defining a threshold for chromatic contrast

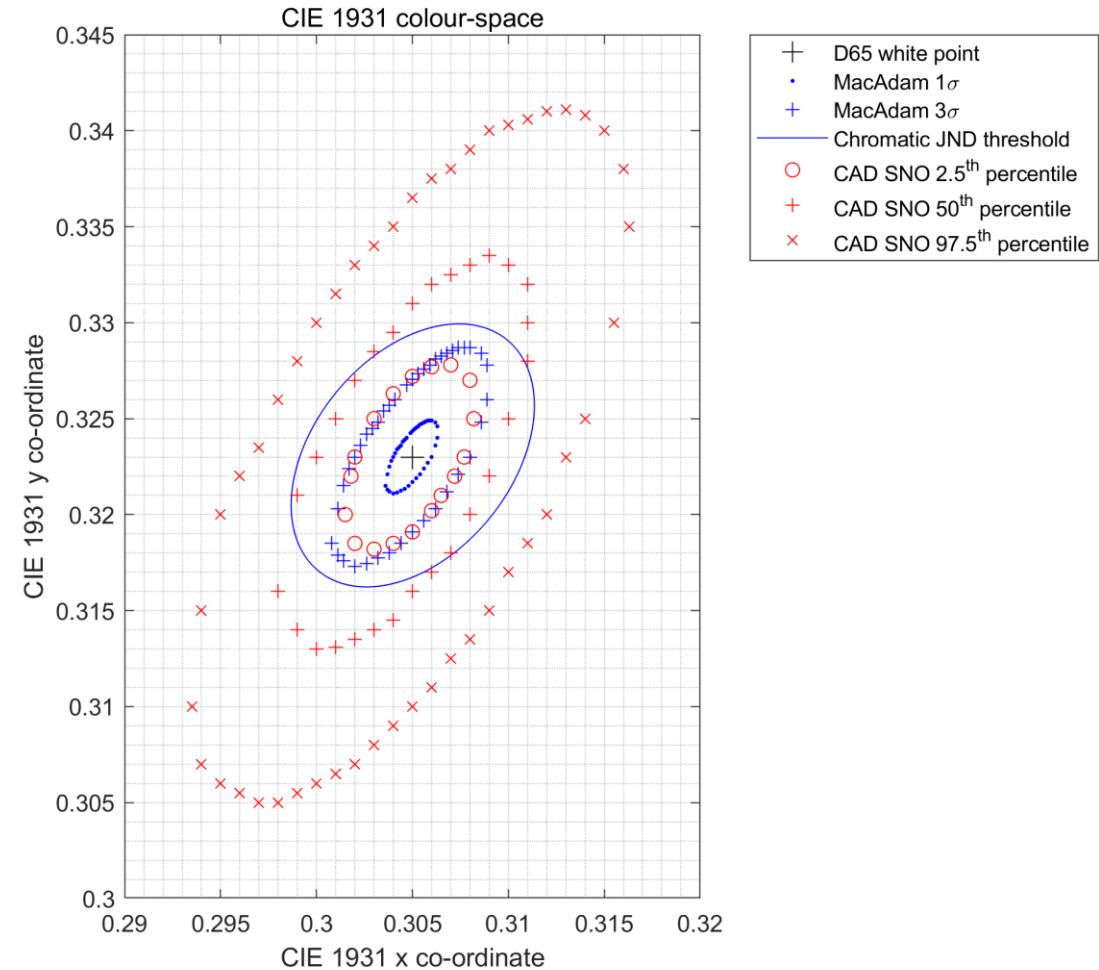
MacAdam defined a series of ellipses that defined the limit of chromatic sensitivities in terms of standard deviation of trial results.

- Align to a 50% confidence level in a difference in chromaticity.
- Based upon this study a previous chromatic Just Noticeable Difference (JND) has been defined.

Colour Assessment and Diagnosis (CAD) test from City, University of London provides further definition.

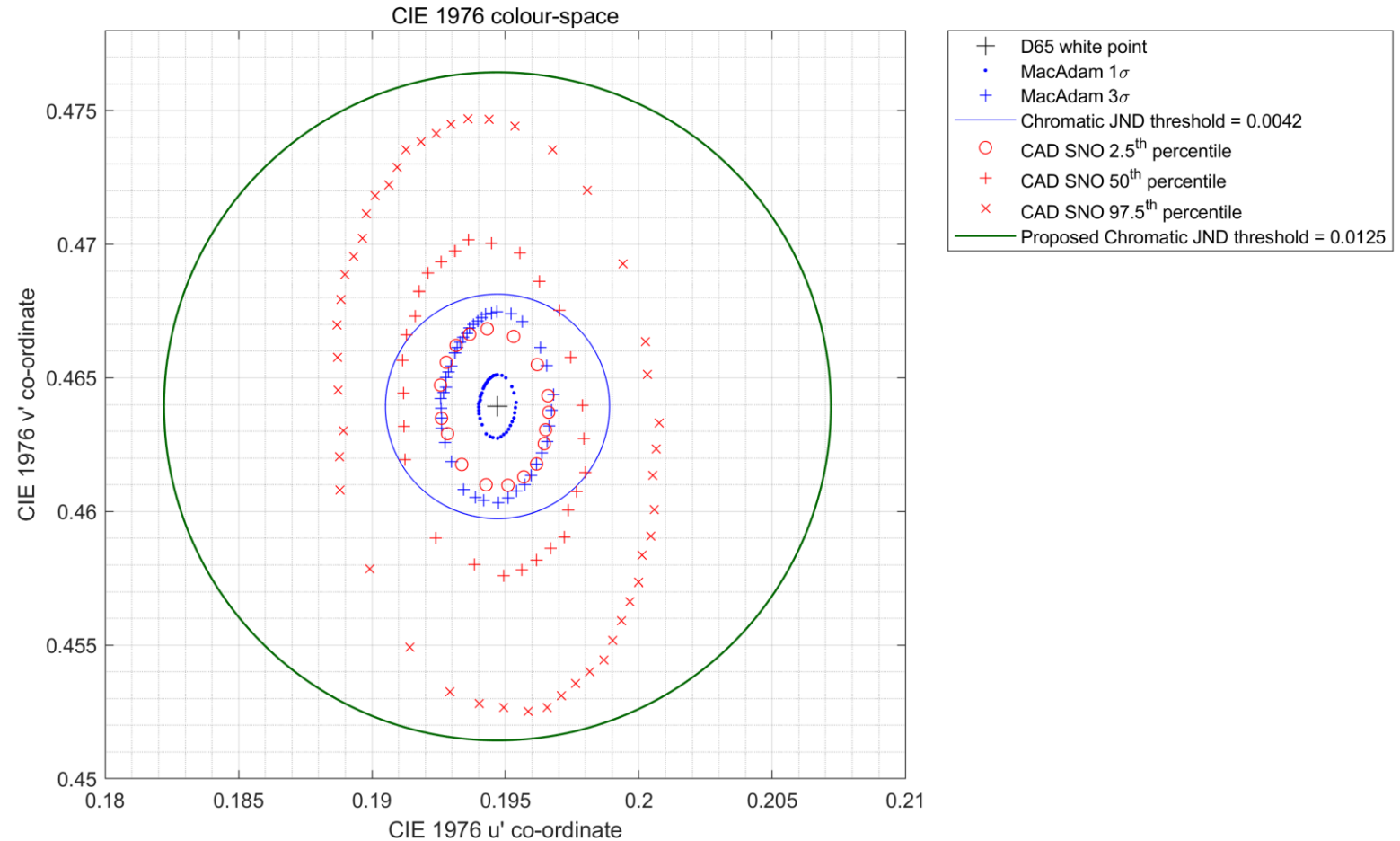
- 70.7% stability point providing greater confidence in the colour difference.
- Definition of limits for a Standard Normal Observer, (SNO) corresponding to 2.5th, 50th and 97.5th percentile of the population.
- The use of the SNO allows for age related losses in sensitivity to colour.

CAD test is standard used by the UK Civil Aviation Authority (CAA) for assessing pilots for a colour vision deficiency.



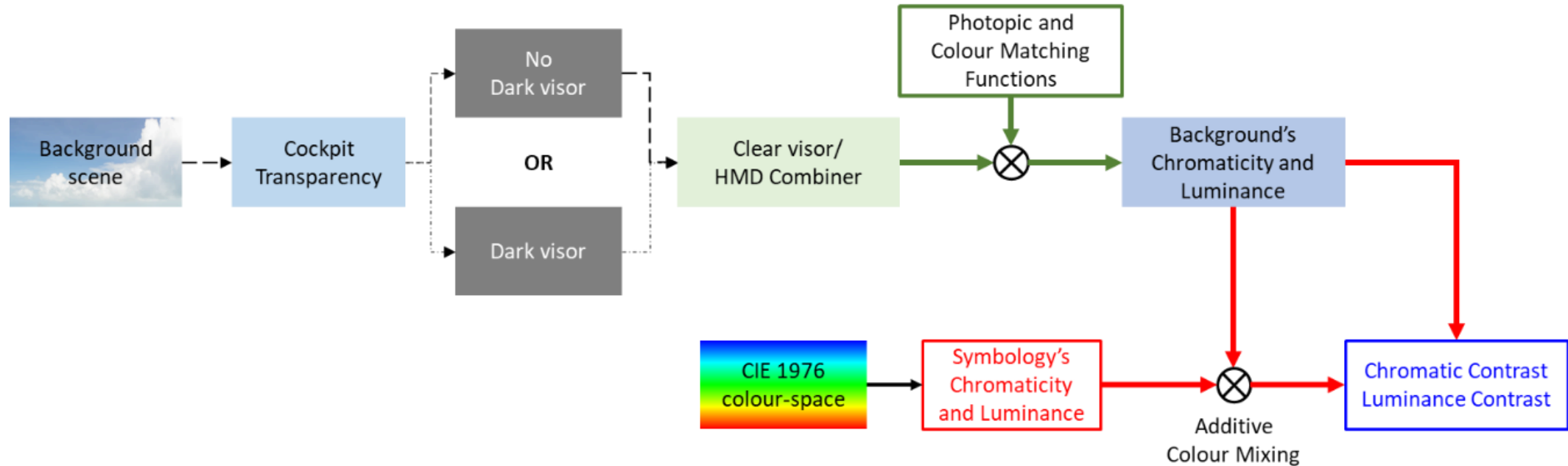
Defining a threshold for chromatic contrast

- Ellipses in the CIE 1931 colour-space transformed into CIE 1976 colour-space.
- Ellipses aligned to co-ordinate frame.
- JND threshold of 0.0042 bounds the MacAdam ellipses...
...but doesn't bound the upper percentiles of the CAD thresholds.
- Proposed chromatic JND threshold encapsulates CAD SNO at value of 0.0125 units in CIE 1976 colour-space.
- Proposed value for model is 0.0500 units.
 - Corresponds to $4\sigma = 4 \times 0.0125$
 - Seen by $\sim 99.99\%$ of colour normals.



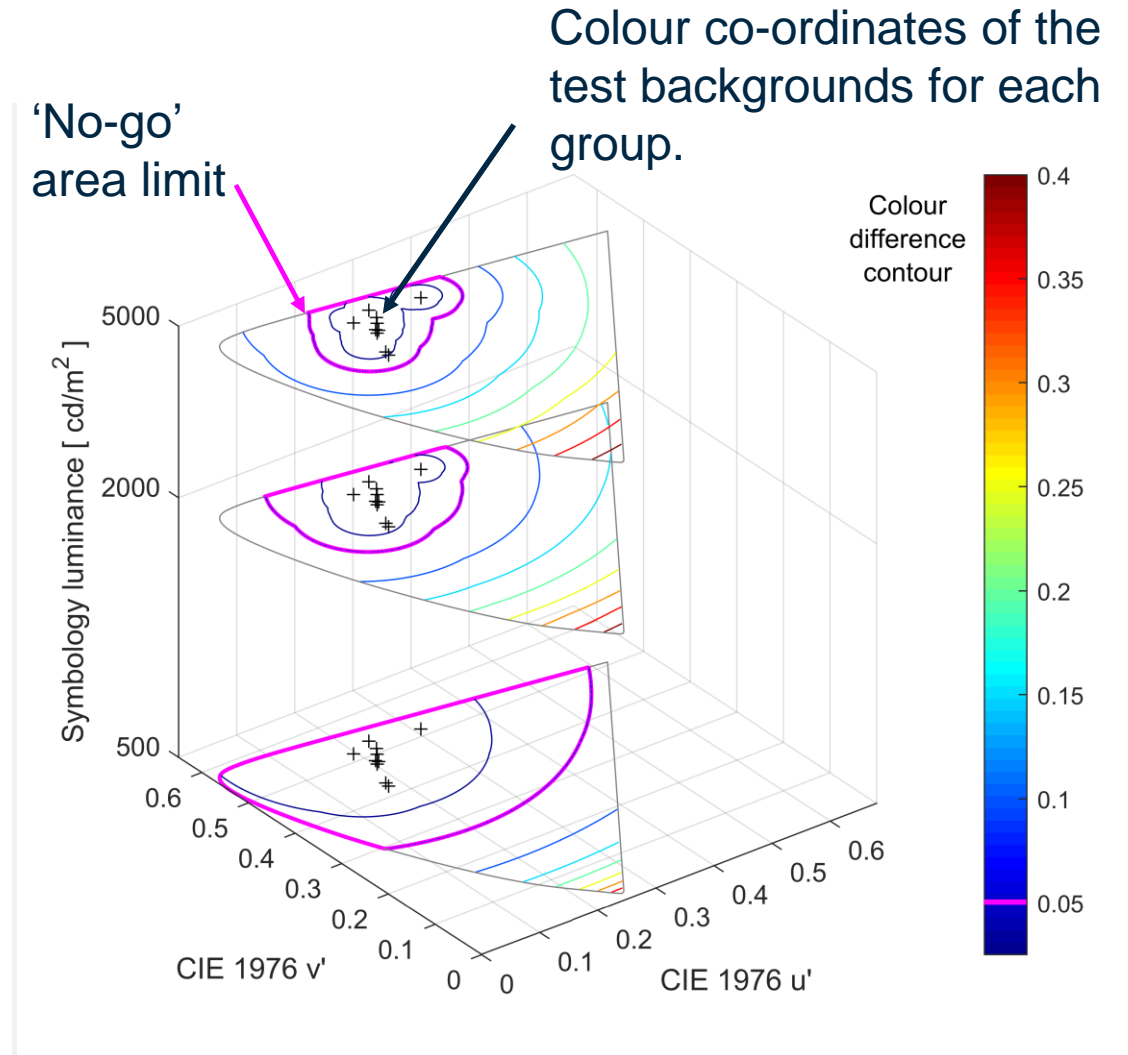
Model components

Initial top level model translated into the computation blocks used to understand the problem space.



Results – All backgrounds

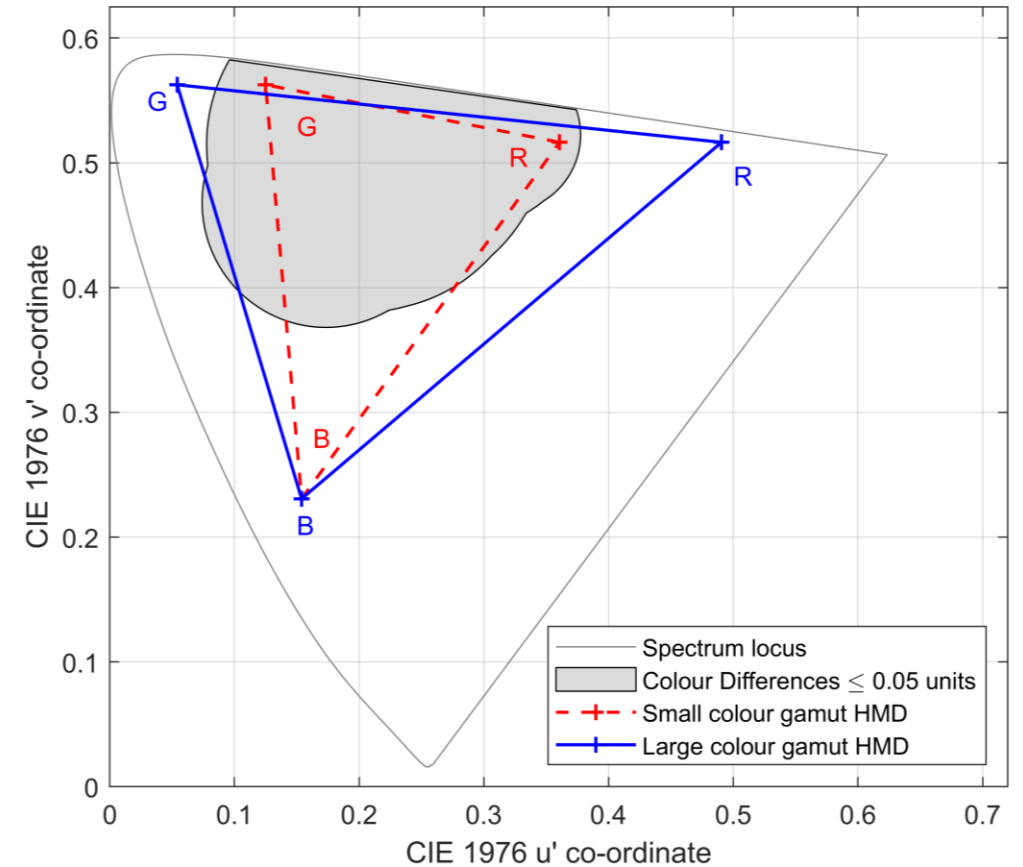
- The results for all background conditions have been combined into a single graph.
- Model predictions shown for three symbology luminance values:
 - 500 cd.m^{-2}
 - 2000 cd.m^{-2}
 - 5000 cd.m^{-2} .
- The luminance of the symbology is key to defining the available colour gamut and ensuring sufficient chromatic contrast against the background scene.



Discussion

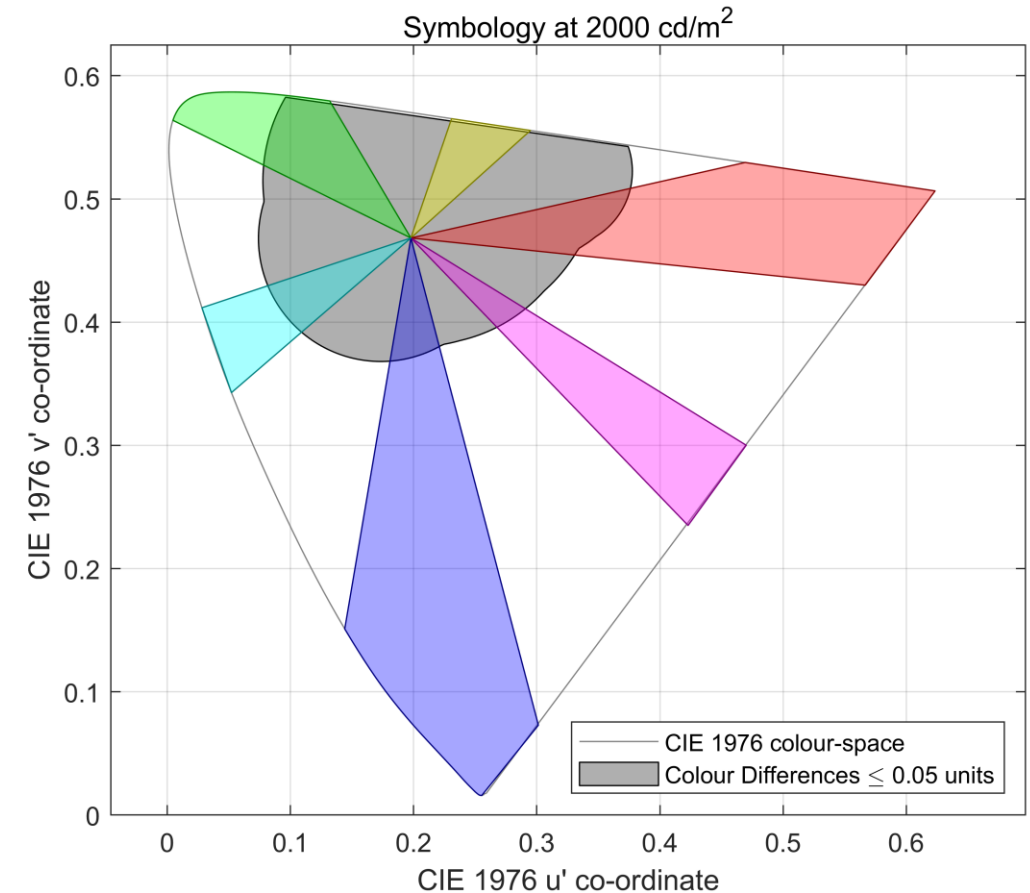
Factors that will affect the ability to use colour symbology:

- Size of the colour gamut of the display;
- Luminance of the display;
- The criteria for a colour difference of >0.05 units in CIE 1976 colour-space;
- Additional protective coatings applied to the clear visor.



Conclusions

- A chromatic threshold of 0.0125 units in CIE 1976 colour-space has been defined.
 - Based upon the chromatic threshold for at least 97.5% of the population of 20-year old SNO
 - Aligns to a probability of detection of 70.7%.
- A chromatic supra-threshold of 0.0500 units in CIE 1976 colour-space has been defined.
- Based upon the modelling undertaken, yellow and orange do not have sufficient chromatic contrast with the external background scene.
- The brighter you make the symbology, the smaller the size of the 'no-go' area.



Recommendations and acknowledgements

Implications of findings

- Blocks of colour used for symbology should have a separation greater than the supra-threshold value (0.0500) to avoid confusion.
- Yellow and orange are not used as symbology colours due to insufficient chromatic contrast with the background scene.
- To validate these findings, it is recommended that a task oriented, human participant trial should be undertaken.

Acknowledgements

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