Specifying Colour and Maintaining Colour Accuracy for 3D Printing

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Colour research for European Advanced Technology Employment

Marie Curie FP6

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colour in art, science, design, conservation, research, printmaking, digital technologies, textiles.

CREATE organisers invite you to submit an application for their grand finale conference - which will showcase the research activities of those working in colour from a range of backgrounds across Europe. The conference is open to all working in colour: postgraduate students from arts and sciences, artists, industry & the commercial sector and researchers. You will need to submit a full presentation or poster to attend - see ‘how to apply’ for more details. Delegates will also hear key lectures from leading industry professionals, artists, scientists and technologists.

How to apply:
We hope to put together a truly multi-disciplinary programme of presentations, designed to be suitable for a multi-disciplinary audience. Your presentation could be an oral and visual presentation, visual only, sound, performance, demonstration, screening, or a workshop.
To apply, please download an application form and presentation template from the CREATE website at www.create.uwe.ac.uk, and follow the online instructions.

This event is funded by Marie Curie Actions - successful applicants will receive travel and accommodation grants to attend, and will have their submission printed in the CREATE publication ‘Colour Coded’.
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3D printing applications

Problems for artists and designers:

• accurate on-screen pre-visualisation
• colour management methods
• colour gamut and maintaining colour accuracy
Objective

• provide colour tables and palettes that provides the user with a printed reference

• to visualise how the printed colour will appear on a flat surface and on a contoured textured surface

• to assess the affect of different infiltrants and their visual appearance
Accuracy

• ongoing issue with the quality, accuracy and repeatability of the printed colour
• different appearance if printed on the surface to the sides of a 3D object
• strata effect and mottling
• infiltrants helps in sealing the colour and preventing scuffing, but still remains delicate
2 Studies

- Methods for generating coloured blocks
- The visual appearance of different materials and infiltrants
- Measurements of different facets of the coloured blocks
Colour Cube Parraman et al. (2008)

Colour Tiles Stanic et al. (2008)

3D Blocks Walters et al. (2009)
• Gretag Macbeth TC9.18 RGB test chart printed on Z-Corp Spectrum 510

• surface is then waxed

• colours selected from the test chart not from the screen
A colour picker is used in Photoshop to select, record and create colour patches.

Working in Adobe RGB six 320x320 pixel colour faces are generated with colour hue patches of red, green-blue, cyan, magenta, black and white.

Generating the colour cube.

A colour picker is used in Photoshop to select, record and create colour patches.

and...
• Imported to 3D CAD software and applied to the facets of a 3D cube
• Printed in plaster using a powder binder on Z-Corp Spectrum 510
• Surface sealed with wax
Each face divided into a 4 x 4 grid of 80 x 80 pixels
RGB values are added as a separate layer
Generating the 3D blocks

Orientation of the colour test block in the 3D printing software

Design of 3D test blocks
Using the Gretag Macbeth Colour Checker sRGB values
Measurements

Colour Differences between:

- Colour net A & Colour net B
- Colour net A & Colour cube C

\[ \Delta E \text{ of net A and net B} \]
\[ \Delta E \text{ of net A and cube C} \]
Measurements

- A GretagMacbeth EyeOne spectrophotometer, with D50 illuminant and 2° standard colorimetric observer was employed.

- The colour differences are described as Delta (Δ)E CIE 2000.
Delta-E ($\Delta E$) provides the total colour difference between one colour and another.

The average viewer can notice the difference between two colours that are 5-6 delta-E apart. An expert eye can differentiate two colours that are 3-4 delta-E apart.
Average overall colour differences

<table>
<thead>
<tr>
<th>Average Colour Difference</th>
<th>ΔE of net A and net B</th>
<th>ΔE of net A and cube C</th>
</tr>
</thead>
<tbody>
<tr>
<td>white-turquoise-yellow-green</td>
<td>2.6</td>
<td>4.4</td>
</tr>
<tr>
<td>dark-blue-blue-green-turquoise</td>
<td>2.5</td>
<td>8</td>
</tr>
<tr>
<td>yellow-green-red-brown</td>
<td>4.8</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Measurements

- Measurements were made to four faces of each block:
  - (A) top face,
  - (B) front face,
  - (C) side face,
  - (D) curved surface at 45 degree angle
Five sets of 24 colour test blocks were available for colour measurement as follows:

Set 1  Z-Corp 510  not sanded  waxed
Set 2  Z-Corp 510  sanded  waxed
Set 3  Z-Corp 510  sanded  Z-Bond
Set 4  Z-Corp 650  sanded  waxed
Set 5  Z-Corp 650  sanded  Z-Bond

Paraffin wax and cyanoacrylate infiltrants
Results of colour differences between top surface, marked A, and other surfaces, front, side and curved (45° angle), marked B, C, and D respectively.

DE between top surface, marked A, and respective other surfaces, expressed as average for all the samples.
Results of colour differences between top surface, marked A, and other surfaces, front, side and curved (45° angle), marked B, C, and D respectively.

DE between top surface, marked A, and respective other surfaces, expressed as average all the colours on sets 1 to 5: Set 1 Z-Corp 510 not sanded waxed; Set 2 Z-Corp 510 sanded waxed; Set 3 Z-Corp 510 sanded Z-Bond; Set 4 Z-Corp 650 sanded waxed; Set 5 Z-Corp 650 sanded Z-Bond
Results of colour differences between top surface, marked A, and other surfaces, front, side and curved (45° angle), marked B, C, and D respectively.

dE between measured values of GretagMacbeth ColorChecker chart and top surface, marked A, of sets 1 to 5: Set 1 Z-Corp 510 not sanded waxed; Set 2 Z-Corp 510 sanded waxed; Set 3 Z-Corp 510 sanded Z-Bond; Set 4 Z-Corp 650 sanded waxed; Set 5 Z-Corp 650 sanded Z-Bond
Designer Case Study

Peter Walters
Designer Case Study
Peter Walters
Unwaxed
Waxed
Conclusions

• methods aid artists and designers in visualising, previewing and specifying 3D printed colour
• profile made from Gretag Macbeth chart can be used to preview how the printed and waxed colour will appear
• infiltrants create different surface qualities
• considerable scope for further colour development
Thank you

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