



Reproducing stained glass on a wide-format ink jet printer

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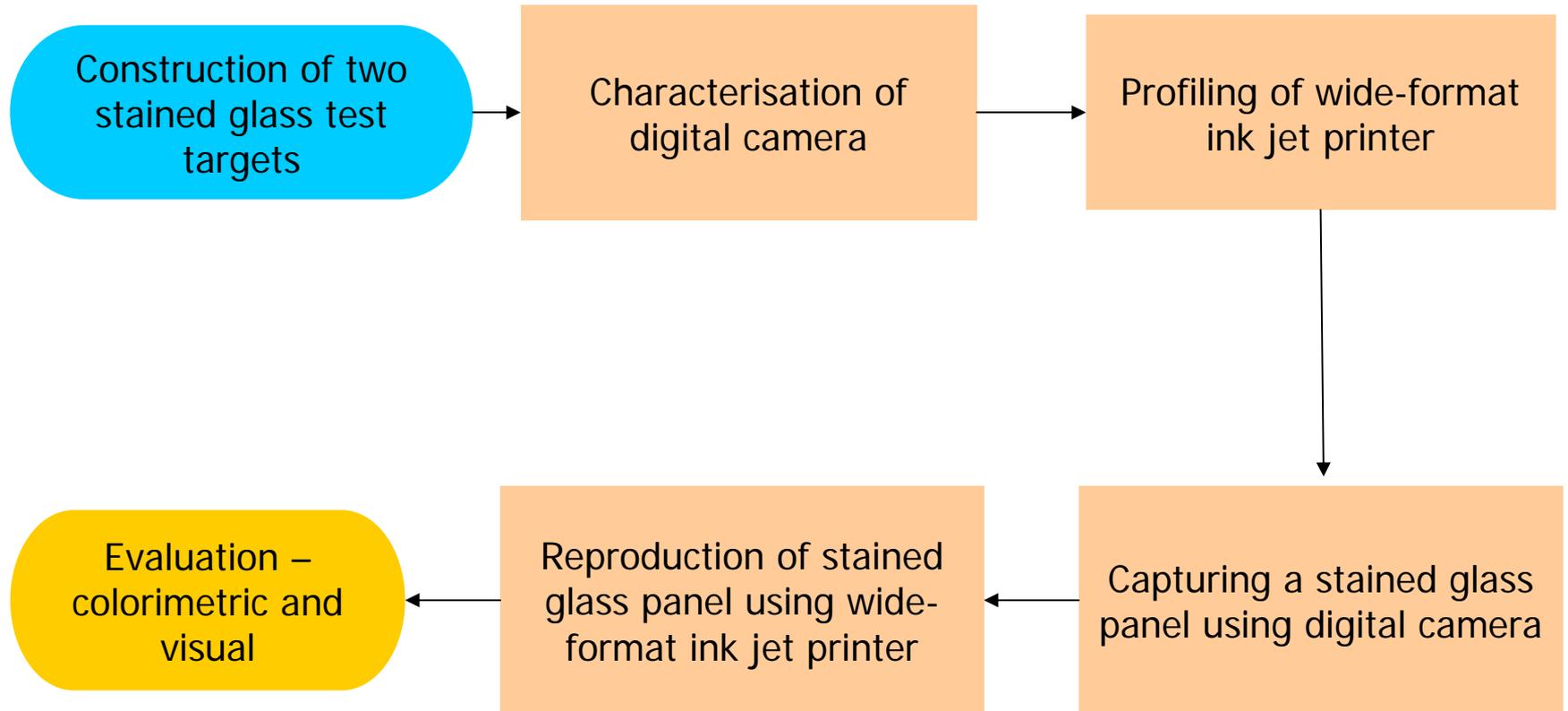
London College of Communication, London



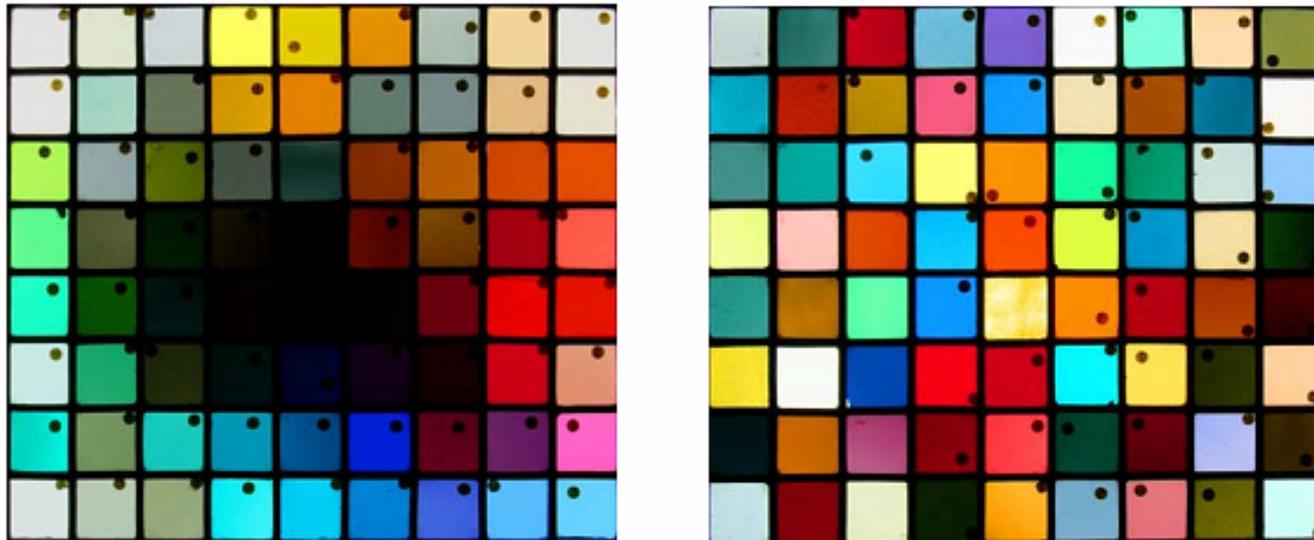
Project objectives

- To reproduce two stained glass targets (each with 72 glass tiles) on transmissive material and evaluate the reproduction through physical measurement
- To make a colour reproduction of stained glass panel by printing on transmissive material with the help of wide format ink jet printer
- To evaluate the quality of reproduction through measurements and psychophysical experiment

Project Workflow



Stained Glass Test Targets

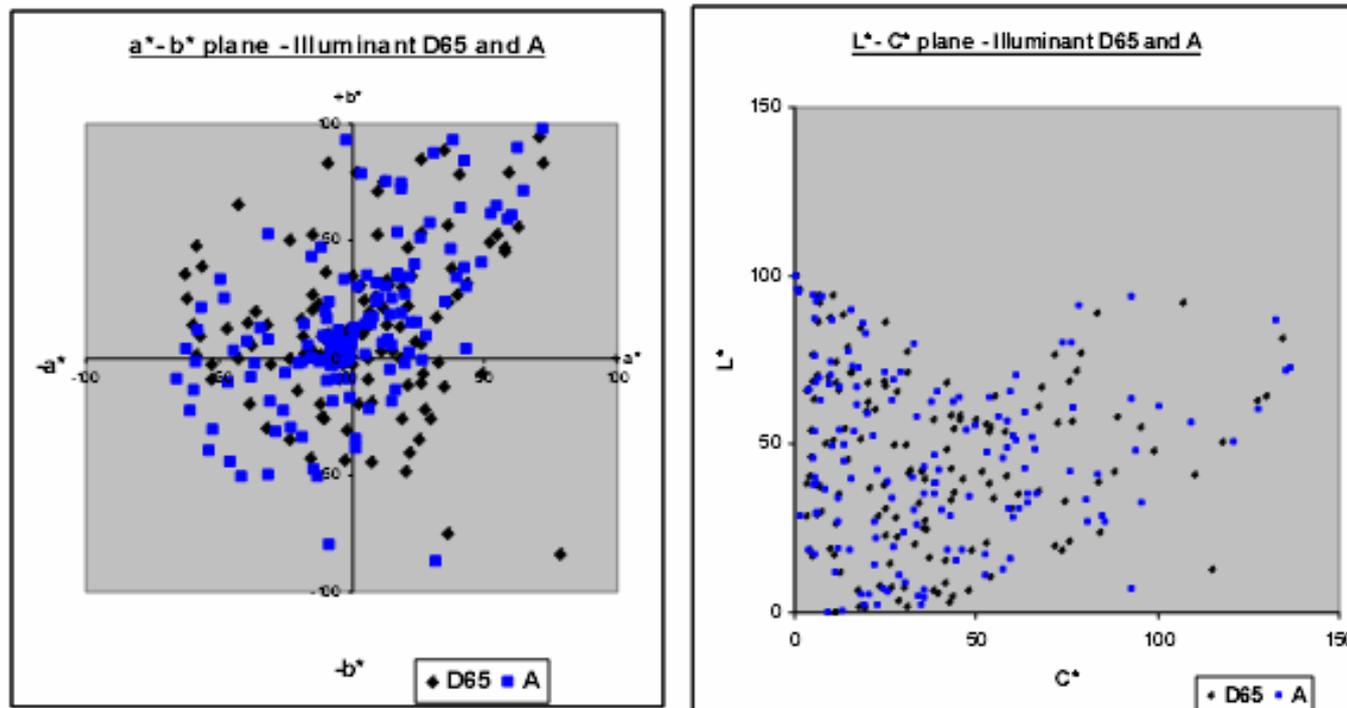


Reference stained glass test target (left) and training test target (right)

- Each target contains 72 glass tiles of size 4 x 4 cm
- Arranged in rectangular layout of 8 rows by 9 columns

Stained Glass Test Targets

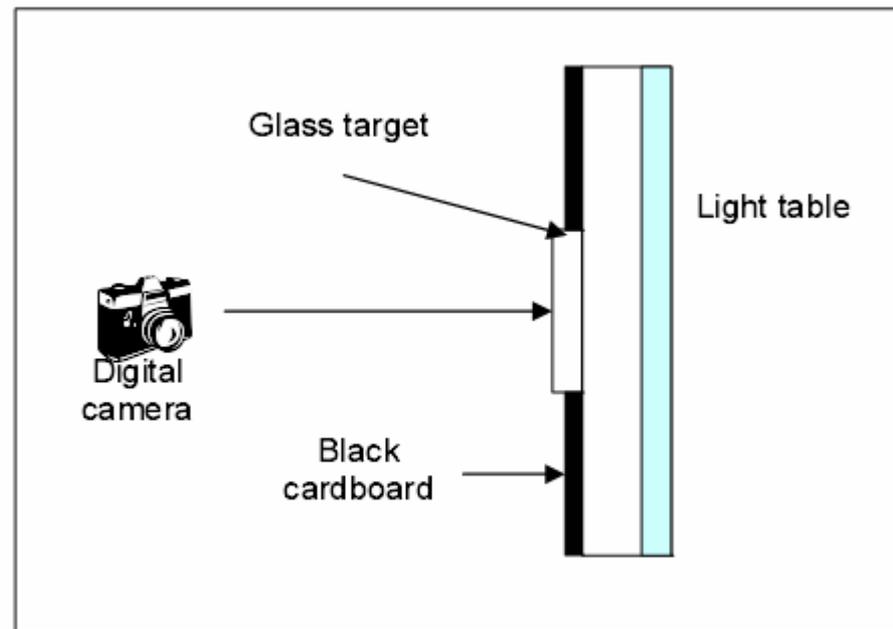
- Measurement of glass tiles by spectrophotometer and calculation of their colorimetric values for illuminant D65 and A



Distribution of stained glass tile colours in CIELAB $a^* - b^*$ and $L^* - C^*$ planes for illuminants D65 and A

Backlight Illumination

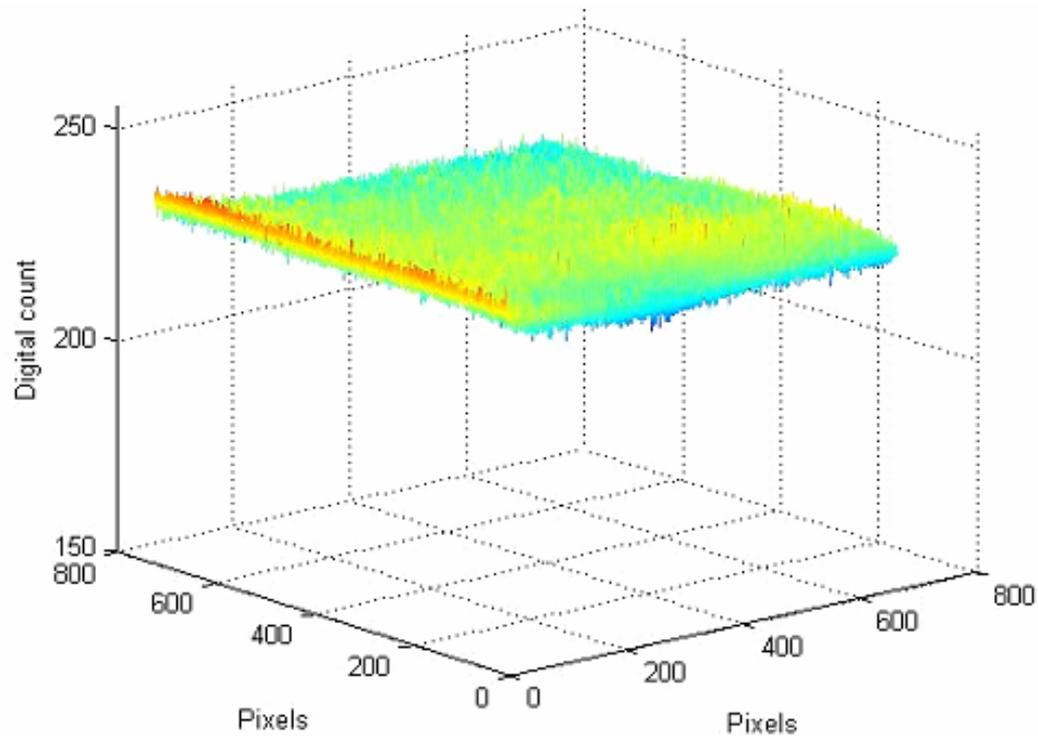
- ❑ Camera used: Leica *Digilux II*
- ❑ A large light table was used to backlight the stained glass targets
- ❑ Luminance level: 3350 cd/m²



Setup for image capture of stained glass targets

Backlight Illumination

- Non-uniformity of illuminating surface – capturing 'white image'
- Spatial uniformity of the white image was very good
- Correction for non-uniform illumination was applied to all images



Spatial non-uniformity of white image

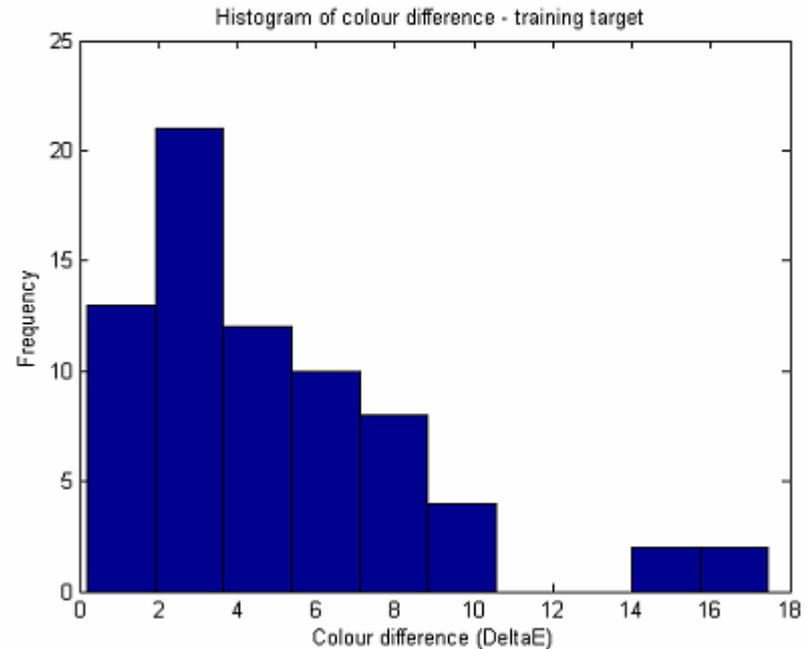
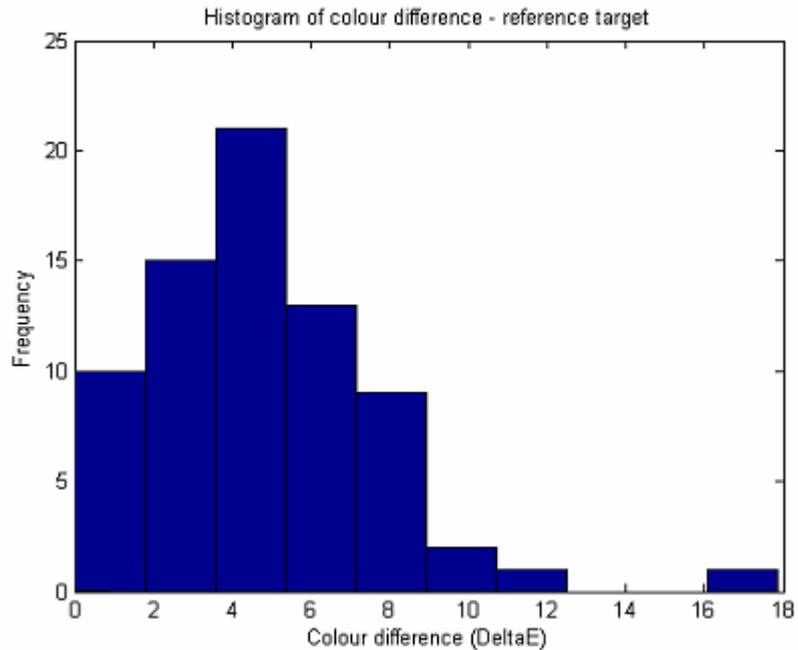
Characterisation of Digital Camera

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = D \begin{bmatrix} R \\ G \\ B \\ R^2 \\ G^2 \\ B^2 \\ R^3 \\ G^3 \\ B^3 \\ RG \\ GB \\ RB \\ GR^2 \\ RG^2 \\ RB^2 \\ BR^2 \\ BG^2 \\ GB^2 \\ RGB \end{bmatrix}$$

- Characterisation: polynomial regression method with least-square error minimisation
- Third-order polynomial generally gives sufficient accuracy
- Matlab was used to obtain the coefficient matrix D with 3 x 19 coefficients

Characterisation of Digital Camera

- Calculated XYZ values were transformed into CIELAB space
- Average ΔE^*_{ab} - reference target: 4.74, training target: 4.90



Histograms of colour difference with 3rd order polynomial regression
Reference target (left) and training target (right)

Profiling of Wide-format Ink jet Printer

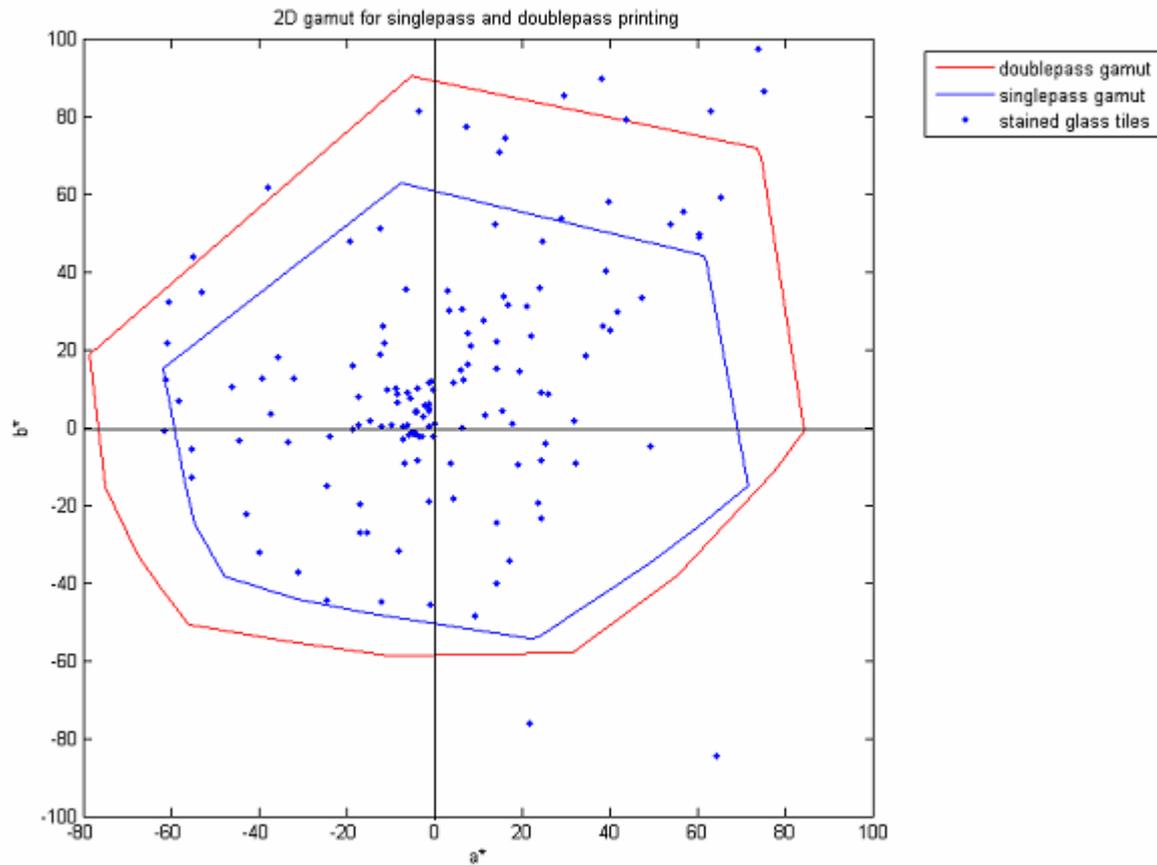
- ❑ Printer: Inca Eagle (Concorde Graphics, London)
- ❑ Substrate: Clear Acetate (20 micron)
- ❑ Single-pass and double-pass modes can be used.

Profiling

- ❑ Colour test chart (IT8.7/3) was printed on acetate sheet
- ❑ Colour patches were measured using GretagMacbeth SpectroscanT
- ❑ ICC profiles were created with GretagMacbeth ProfileMaker software



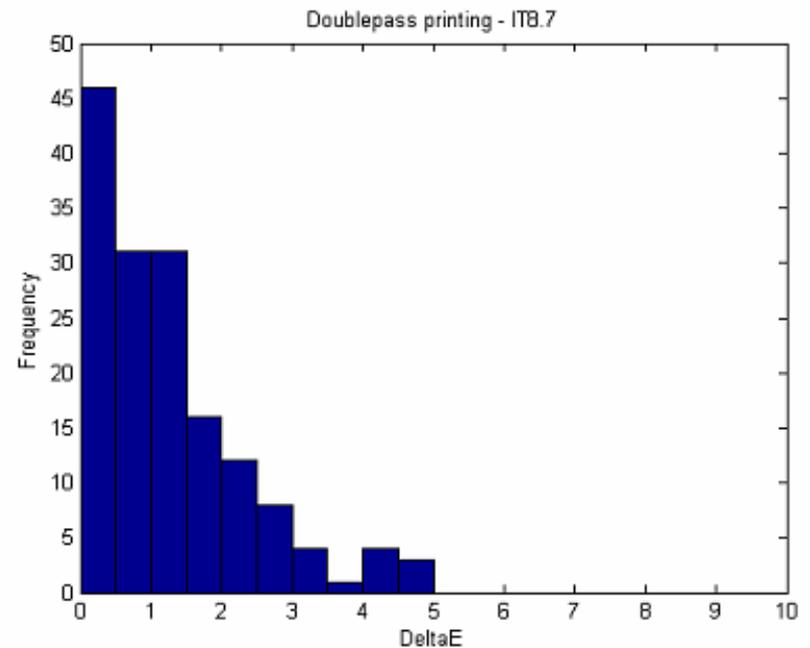
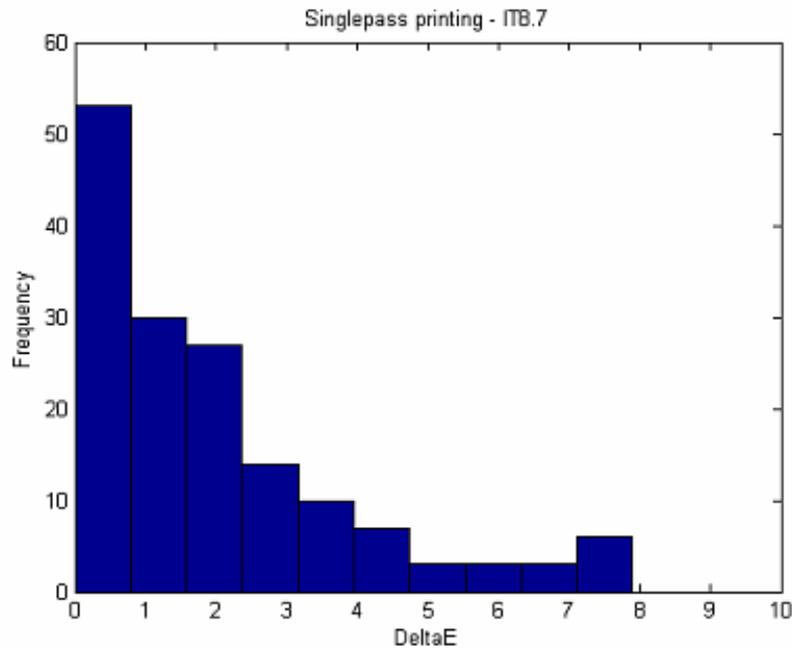
Profiling of Wide-format Ink jet Printer



Colour gamut of single-pass and double-pass profiles
and distribution of stained glass tiles in a^* - b^* plane

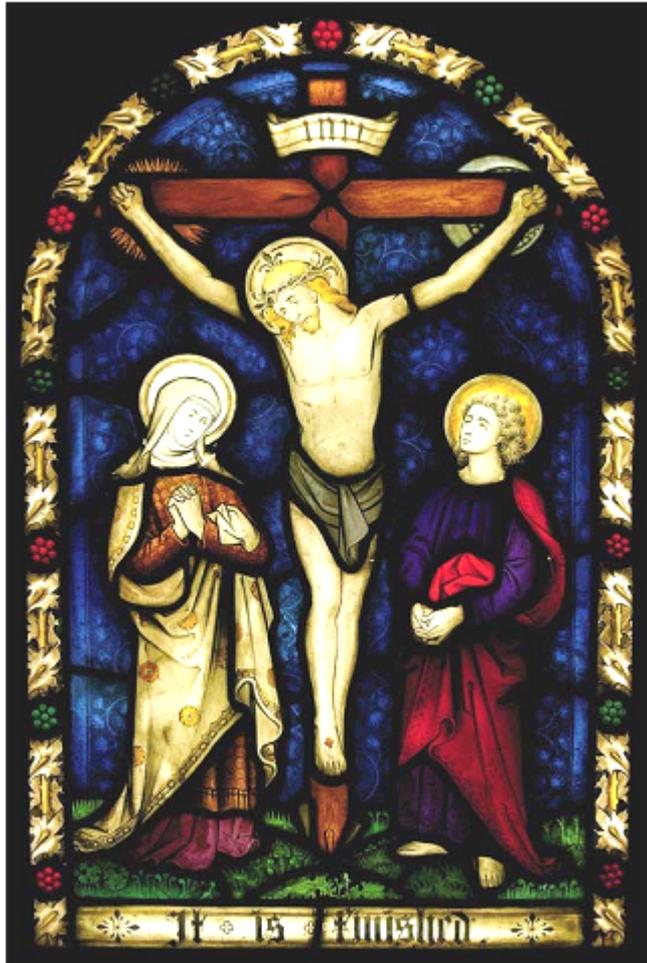
Profiling of Wide-format Ink jet Printer

- Evaluation of profiles: round-trip test
- Mean ΔE^*_{ab} - single-pass profile: 1.95, double-pass profile: 1.27



Histograms of colour differences for single-pass (left) and double pass (right) printing profiles using IT8.7/3 chart

Visual Evaluation



Stained glass panel

- ❑ Life-size reproductions of stained glass panel
- ❑ Stained glass captured by Leica *digilux II* digital camera
- ❑ Image transformed to CIELAB by polynomial characterisation of camera
- ❑ Single-pass and double-pass printer profiles applied to image separately
- ❑ Two images printed onto clear acetate using Inca Eagle wide-format ink jet printer



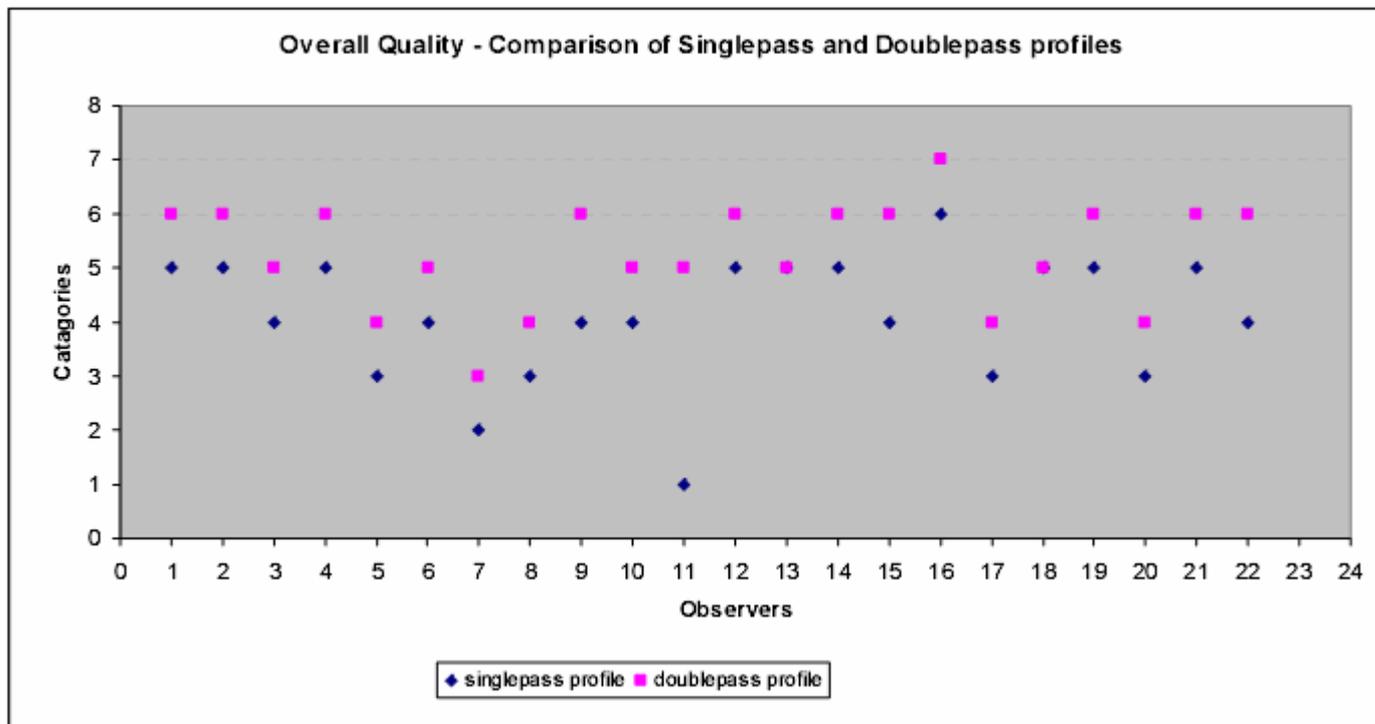
Visual Evaluation

Psychophysical experiment

- ❑ Method: category judgement
- ❑ Attributes judged: colour saturation, sharpness and overall quality
- ❑ No. of observers: 22
- ❑ Comparison of the printed reproduction with the original stained glass panel
- ❑ Categories:
 1. Does not match at all
 2. Very poor match
 3. Poor match
 4. Average match
 5. Close match
 6. Very close match
 7. Exact match

Visual Evaluation

- Reproduction with double-pass printing (average score 5.3) was preferred by all observers to that with single-pass printing (average score 4.0)
- Visual results agreed with the measured colour difference metrics



Results of category judgement experiment for overall image quality



Thank you!