International Standard

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# Graphic technology — Measurement and one-parameter representation of translucency

*Technologie graphique — Mesurage et représentation à un paramètre de la translucidité*

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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# Contents

Page

# Foreword

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# Introduction

Advances in 3D printing allow the combination of multiple printing materials with different optical properties into a single object at a very high resolution. This allows the reproduction of not only the object's shape but also its visual appearance attributes, in particular colour and translucency.

Many existing 3D file formats encode spatially resolved information of (albedo) colour and opacity of an object as a RGBA texture mapped to its 3D geometry. This information is widely used in rendering, where the RGB colour information is typically interpreted as device independent standard RGB and A (also called α) as a blending or mixing parameter to produce transparent overlays in image composition assuming additive colour mixture.

Using an additive colour mixture model is simple, computationally efficient and robust for on-screen display, but it has severe shortcomings, i.e. light is altered by matter subtractively, not additively, i.e. many real transparent materials cannot be described by this interpretation. As a result, renderings employing α as an additive mixture parameter are suitable for illustrative purposes rather than accurately simulating the appearance of real objects.

Therefore, it is highly desirable to capture perceived translucency of real objects within a single parameter, foremost because it allows the seamless continued use of existing image and 3D file formats, and it is supported by various existing 3D design and image manipulation tools.

For the purpose of reproducing translucent objects by 3D printing, a few properties of α are desired.

— α is linked to a measurable quantity. Only then, can α be assigned to real materials via measurements and print material arrangements can be adjusted to match this quantity.

— For print reproductions, a perceptually uniform scale for α is important, allowing the minimization of perceived errors rather than physical ones. The viewing conditions for this scale agree with the RGB conditions to ensure consistency of colour and translucency. In colour printing, the viewing/illuminating geometry is specified by the International Color Consortium and is supported by colour and spectrophotometric measurement devices employed in graphic arts, which are used to calibrate the printers.

— If an object made of a translucent material is scaled (most commonly shrunk) for printing, it is desirable that average light transport distances can be adjusted accordingly to preserve perceptual translucency cues. This is demonstrated in Annex A. Therefore, α should be adjustable to the print size in relation to the original object size in an intuitive, predictable and computationally efficient way.

— For design purposes, the absence of cross-contamination between the chromatic channels (chroma and hue) and α is important, i.e. that changing the chromatic channels has no effect on perceived translucency and vice versa, for the specified viewing conditions.

Translucency alpha is a one-dimensional parameter defined for all materials, without imposing constraints on their spectral refractive index, absorption and scattering properties, or phase functions. Translucency alpha is assigned to a material by selecting a virtual reference material matching in transmittance and edge loss when measured as described on a 4 mm flat tile (reference thickness). The virtual reference materials are defined by wavelength-independent scattering, absorption and refractive indices as well as an isotropic phase function.

The bigger the intrinsic optical properties deviate from the optical properties of the virtual reference material the bigger will be the deviation of perceived translucency for samples with thicknesses other than 4 mm. Real material can change in scattering phase function and can possess wavelength-dependent scattering and absorption (the virtual reference materials are defined by an isotropic phase function and wavelength independent absorption and scattering). This is the limitation of using just one parameter to describe the magnitude of translucency.

It is worth mentioning that various publications show that the degree of perceived translucency is judged predominantly at thin structures,[2],[3] i.e. it is plausible that the virtual reference material that best mimics