

Title: New quantities for the measurement of appearance

Abstract

Novel metrological solutions are required in several areas relating to the quantitative control of the visual appearance of surfaces, based on measuring the optical properties of materials. There is an urgent need for advanced metrology to reduce uncertainties in the measurement of the bidirectional reflectance distribution function (BRDF) and for the realisation of metrological traceability for BRDF measurements from micrometric scale objects. For measurements of the bidirectional transmittance distribution function (BTDF) and the bidirectional scattering surface reflectance distribution function (BSSRDF), primary reference facilities and transfer artefacts should be developed.

Keywords

Reflectance, transmittance, goniospectrophotometry, BRDF, BTDF, BSSRDF, polarisation, appearance, material

Background to the Metrological Challenges

The appearance of products and visual branding are important drivers for consumer purchase decisions because they underpin perceptions of 'quality' and 'desirability'. The control of appearance is thus essential for almost all industrial fields. The global challenge of the measurement of visual appearance has been pointed out by several organisations, such as EURAMET Technical Committee for Photometry and Radiometry (TC-PR) [1] and the International Commission on Illumination (CIE) [2].

The EMRP project IND52 xDReflect initiated new metrology to support BRDF measurements and developed facilities to cover a diversity of industrial needs. The main outputs of that project are now progressing at the normative level within the EMPIR project 16NRM08 BiRD. This has allowed an anticipation of future needs for BRDF, which are an improvement of angular resolution and a reduction of spectral bandwidth, while guaranteeing smaller uncertainties. Additionally, recent advances in material science have made available an unprecedented control of matter at the nanoscale. The challenge of translating small-scale designs into large-scale effects and perception relies on determining the effect of the residual coherence of light (speckle effect) and polarisation, and on maintaining traceability when switching from macroscopic surfaces (cm²) to microscopic surfaces (µm²). Addressing these matters will open a completely new area in the field of spectrophotometry, fully aligning metrology to current industrial needs.

Diffuse transmittance measurements are still performed with a relative methodology based on integrating spheres to determine total transmittance, transmittance haze or clarity. Demand is growing for the visual characterisation of frosted glass, food packaging or horticultural fabrics through the BTDF. While BTDF measurements have been reported and carried out widely, there is no standard definition of the measurand. BTDF measurements are of interest not only for particular samples such as diffusers for luminaires or glazing windows, but also to calibrate reference materials for the integrating sphere methods. While many NMIs hold CMC entries for these integrated quantities, very little work has been done to establish the equivalence of the scales with empty space as the reference. Urgent action is required to clarify the measurand of BTDF, set up primary references facilities and consolidate the traceability with sphere-based measurements.

Translucent materials are ubiquitous, and simulating their appearance requires knowledge of accurate physical parameters, such as scattering and absorption coefficients, and the phase function of the material, which are parameters difficult to acquire. The function that allows translucency to be characterised is BSSRDF, a quantity that is challenging to measure accurately as it depends on 10 parameters including the position and direction of incoming and outgoing light rays on the surface, and their wavelength and polarisation. A traceable goniospectrophotometric procedure to measure this quantity, used in computer graphics to render the appearance of complex commonplace materials like skin, stones or leaves, has never been described. A full

traceability chain for BSSRDF is required to check and improve the rendering models that are at the basis of virtual prototyping, video games and diagnostic tools in dermatology.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of the visual appearance of surfaces.

The specific objectives are

1. To address advanced metrological issues related to measurement of the bidirectional reflectance distribution function (BRDF), including polarisation, speckle and retroreflection induced effects, in order to reduce by a factor 2 the measurement uncertainty to 0.1 % ($k = 2$) in the visible wavelength range.
2. To develop primary reference facilities and standard artefacts for the measurement and dissemination of the bidirectional transmittance distribution function (BTDF) as a traceable quantity.
3. To develop primary reference facilities and standard artefacts for the measurement and dissemination of the bidirectional scattering surface reflectance distribution function (BSSRDF) as a traceable quantity.
4. To establish a full metrological traceability of the BRDF from tiny objects (micrometric scale) to regular objects (centimetric scale).
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, spectrophotometer manufacturers), standards developing organisations (ISO, CIE) and end users (e.g. automotive industry, video game developers, healthcare sector, visual arts sector, architectural materials manufacturers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP and EMPIR projects IND52 xDReflect and 16NRM08 BiRD and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to industry and other stakeholder sectors.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

- [1] EURAMET TC-PR Roadmap for Industry, available at https://www.euramet.org/Media/docs/Publications/roadmaps/TC_PR_Industry_Roadmap_2012_Text.pdf
- [2] CIE Research Strategy (August 2016), available at http://files.cie.co.at/874_CIE%20Research%20Strategy%20%28August%202016%29%20-%20Topic%207.pdf