18SIB03 BxDiff

Publishable Summary for 18SIB03 BxDiff
New quantities for the measurement of appearance

Overview

Product appearance and visual branding are important drivers for consumer purchase decisions, as they underpin perceptions of 'quality' and 'desirability'. The project aims to advance primary metrology in spectrophotometry to meet industrial needs for the quantitative measurement of appearance. This will be accomplished by i) defining new spectrophotometric quantities, ii) taking previously ignored corrections terms into account, and iii) developing new traceable spectrophotometric primary references which will provide new tools for quality control and more realistic solutions for virtual prototyping. This research will benefit different industrial sectors e.g. automotive, paper, cosmetic and 3D-printing.

Need

Industry is developing increasingly complex materials that require bidirectional reflectance measurements. Consequently, traditional reflectance references based on a single angular measurement configuration will be deemed obsolete in the future. New commercial bidirectional spectrophotometers are diverse, flexible and high performing. National Metrology Institutes (NMIs) must continue supporting the ongoing revolution in spectrophotometry by providing bidirectional reflectance calibration services for angular configurations different than the classical 0/45 configuration. The primary scales kept by participating NMIs have never been compared for angular configurations, which are representative of those used in the new generation of commercial products. Furthermore, the influence of common optical phenomena e.g. speckle and polarisation, has never been thoroughly studied in Bidirectional Reflectance Distribution Function (BRDF) measurements and might have a non-neglecting effect in uncertainty budgets.

The appearance of objects depends not only on the material(s), colour, shape and lighting environment, but also on the observation distance. Therefore, the optical properties of materials must be measured at different scales: from the macroscopic to the microscopic.

Bidirectional Transmittance Distribution Function (BTDF) as a quantity is the angle dependent radiance in transmission, referred to the irradiance on the sample. While BTDF measurements have been widely carried out, a standard definition for this measurand does not currently exist. BTDF measurements are of interest for diverse applications ranging from diffusers for luminaires to functional glasses for photovoltaic panels, because they could allow better performance, characterisation and efficiency. Thus, the measurand of BTDF must be studied, primary facilities must be set up and traceability must be consolidated with sphere-based measurements.

Total appearance, as defined by the Commission Internationale de l´Éclairage (CIE), is the contribution of four main visual attributes: colour, gloss, texture and translucency. Currently, there is no metrology infrastructure in place for measuring translucency, even though this attribute is ubiquitous and crucial in many fields such as cosmetics, food, packaging, dermatology, architecture, virtual reality and 3D printing. Quantifying translucency requires traceable measurements of the Bidirectional Scattering Surface Reflectance Distribution Function (BSSRDF), which are not presently available.

Objectives

The overall goal of this project is to advance primary metrology in spectrophotometry. This will involve defining the new quantities Bidirectional Transmittance Distribution Function (BTDF) and Bidirectional Surface Scattering Reflectance Distribution Function (BSSRDF), developing primary facilities for their realisation, and further improving the measurements of Bidirectional Reflectance Distribution Function (BRDF). The specific objectives of the project are:

1. To address advanced metrological issues, i.e. speckle and polarisation, related to measurement of the BRDF in order to reduce the measurement uncertainty by a factor of two, down to 0.1 % (k = 2) in the visible wavelength range,
2. To establish a full metrological traceability of the BRDF from very small objects (micrometre scale) to regular objects (centimetre scale),
3. To develop primary reference facilities and reference samples (artefacts) for the measurement and dissemination of the BTDF as a traceable quantity with a relative target uncertainty of 0.5 % (k = 2),
4. To develop primary reference facilities and reference samples (artefacts) for the measurement and dissemination of the BSSRDF as a traceable quantity with a relative target uncertainty of 5 % (k = 2),
5. To facilitate the uptake of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, spectrophotometer manufacturers), standardisation organisations (ISO, CIE) and end users (e.g. automotive industry, video game developers, healthcare sector, visual arts sector, architectural materials manufacturers).

Progress beyond the state of the art and results

Improvement of the measurement uncertainty of BRDF

Building on previous projects EMPR IND52 - xDReflect and EMPIR 16NRM08 - BiRD, the measurement uncertainty for BRDF measurements will be improved by addressing advanced metrological issues such as polarization and speckle induced side effects. This project aims to go beyond the state of the art on this by reaching an uncertainty of 0.1 % (k=2) at 550 nm on white diffusing samples. Additionally, to address the growing need for calibration points performed at out-of-the-plane of incidence, the first comparison of BRDF scales realised in primary facilities in the consortium will be performed at angular geometries including out-of-plane geometries.

Metrological traceability of the BRDF from micrometre to centimetre scale

Metrological traceability of BRDF will be extended by focusing on specific metrological issues related to scalability of BRDF measurements of small size area. These issues must to be understood and accounted for, along with the requirements for such measurements. For the first time, a clear and traceable link between micrometre scale measurement areas and centimetre scale measurement areas will be provided.

Primary reference facilities and standard artefacts for BTDF

The most important classes of diffusers will be reviewed, which will be important for the determination of the measurand for BTDF with the lowest uncertainty. Two primary BTDF facilities will be developed to provide traceability for different sample classes or types e.g. frosted glass. The congruence of the scales will be verified by a comparison, aiming at an expanded uncertainty of 0.5 % (k=2). The traceability will then be tested in a second round of comparisons using existing goniospectrophotometers at NMIs, as well as commercial set-ups.

Moreover, a greater insight into the precise BTDF will be investigated in order to improve the results obtained with existing integrating sphere measurements, as the results for artefacts with properties being far off from the Lambertian model may generate considerable errors.

Primary reference facilities and standard artefacts for BSSRDF

At present, the BSSRDF is not clearly defined as a physical quantity. Moreover, because no primary measuring equipment exists, traceable measurements of subsurface scattering or translucency cannot be provided. This project will go beyond the state of the art by defining the measurand and developing primary reference facilities and standard artefacts for the measurement and dissemination of the BSSRDF as a traceable quantity, with a targeted uncertainty of 5 %. Based on accurate BSSRDF measurements, scattering and absorption coefficients of materials as well as the phase function, will be computed. This will be the first step towards calibration and measurement capabilities for BSSRDF at NMIs.

Impact

This project will have high impact on a wide range of communities. The most direct and early impact is expected in the field of metrology, where new primary measurement facilities and new or improved areas of traceability will strengthen NMIs, but it is envisaged that manufacturers of spectrophotometers and test laboratories will also benefit from the project in the short term. On a longer term, all industries relying on the appearance of objects will benefit from this project, as the advances in measurement will help improving the quality control of real objects, as well as their virtual reproductions.

Impact on industrial and other user communities

The field of spectrophotometry is evolving quickly and new commercial devices are continuously coming to the market. The appropriate characterisation and calibration of all these different types of goniospectrophotometers requires a coordinated effort between European NMIs. By the end of this project, the consortium will be able to provide new and improved calibration services to manufacturers of novel spectrophotometers, R&D industries and others.

The reduction of the BRDF measurement uncertainty and the validation and improvement of BRDF scales will reduce the uncertainty of the calibration for spectrophotometer manufacturers, which will have an immediate effect at the industrial level.

Virtual prototyping is very common in industry nowadays. However, virtual scenes calculated with existing rendering software used for image synthesis are still far from realistic when dealing with sparkle effects, aluminium brushed surfaces, complex environment such as car’s cockpit, or translucent materials such as skin. Traceable BRDF measurements on microscopic surfaces will be used in rendering models to simulate the macroscopic appearance of the object. By providing those tools, this project which will have a direct impact on rendering models and virtual prototyping.

The definition and realisation of BSSRDF, will have a direct impact on different industries e.g. cosmetics, automotive, plastics, pulp and paper as well as on rendering software developers as it will provide the first calibration solution for devices that have already been developed.

Impact on the metrology and scientific communities

Better control of BRDF will have a direct impact on measuring quantities such as diffuse reflectance, gloss and colour. This will lead to reduced Calibration and Measurement Capability (CMC) uncertainties at several participating NMIs, therefore improving the quality and the visibility of European metrology in the field of spectrophotometry. New references for BTDF and BSSRDF measurements will lead to new calibration services at NMIs. This will promote the future development of new Certified Reference Materials (CRM), which will make traceability more accessible to the European metrology community.

Impact on relevant standards

This project focuses on the improvement and development of quantities for the characterisation of the visual and optical properties of materials, which forms the terms of reference of CIE Division 2. It is anticipated that the project will have an impact on the work carried out in several CIE technical committees such as CIE TC2-85 (normalisation on BRDF), CIE JTC12 (measurement of sparkle and graininess) and CIE JTC17 (measurement of gloss). The CIE international vocabulary will be extended by the project through the definition of BSSRDF. International metrology committees such as CCPR and EURAMET-TC-PR will be periodically informed about the progress of this project. New calibration and measurement capabilities (CMCs) will be submitted on BTDF and, after the end of the project, on BSSRDF. As a consequence of this project, normalisation work on the measurement of BTDF and BSSRDF is foreseen.

Longer-term economic*, social and environmental impacts*

By providing new and reliable metrological references in spectrophotometry, this project will improve the quality control of the appearance of objects and its virtual reproduction. The control of appearance is directly linked to the success and the competitiveness of goods. The project will lead to improved rendering models able to better simulate the appearance of complicated objects. The uptake of outputs of the project will benefit computer generated imagery in movies and video games, digital prototyping of products, skin appearance rendering for medical and cosmetic industries, 3D printing, and energy assessment of buildings with glazing materials.

List of publications

There are no publications at this early stage of the project.

Project start date and duration:		1 May 2019, 36 months
Coordinator: Gaël Obein, CNAM	Tel: +33 158 808 788	E-mail: gael.obein@lecnam.net
Project website address: under construction		
Internal Funded Partners: 1. CNAM, France 2. Aalto, Finland 3. CMI, Czech Republic 4. CSIC, Spain 5. DFM, Denmark 6. METAS, Switzerland 7. PTB, Germany 8. RISE, Sweden	External Funded Partners: 9. DTU, Denmark 10. Innventia, Sweden 11. KU Leuven, Belgium 12. UJM, France	Unfunded Partners: 13. CI, New Zealand 14. Labsphere, United States 15. Lucideon, United Kingdom 16. NCS, Sweden 17. SG, France
RMG: -		