Measuring the complexity of non-uniform surfaces: application to the measurement of light quality

Host laboratory: XLIM, Futuroscope-Poitiers site
Institution: University of Poitiers, MIMME doctoral school
Research Team: ICONES (ASALI axis)

Period: October 2024 -September 2027
Funding: ANR SCEALED (CNRS), 2024-2028 (funding obtained)

Supervisors: Noël RICHARD, Christine Fernandez-MALOIGNE

Keywords : Spectral imaging, texture, metrology, complexity, colour, perception

Profile and skills required:
You have a Master 2 or an engineering degree in Signal and Image Processing, EEA, Mathematics or Computer Science with fundamentals in :

- Signal and Image Analysis and Processing,
- Image acquisition, Vision, Computer Vision
- Probability and Statistics, Machine Learning,
- Computer programming (Python, Numpy, Scipy, sklearn…), analysis and development for large-scale matrices, combined documentation management
- Latex tools, Beamer, ...

- Level of French (CECRL): B1
- English level (CECRL): B2

Project abstract :

The main objective of the thesis is to measure the impact of a change in the illumination spectrum in the physical domain (spectral imaging) and in the perceptual domain (imaging in perceptually uniform spaces, such as CIELAB). ***The project hypothesis is that a change in the illumination spectrum of a scene has an impact on the complexity measurement obtained by color or spectral cameras and/or on the perception of observers***.

Based on the state of the art and the results obtained in the ICONES team on color and spectral image analysis, the PhD student will develop various attributes for measuring the textured appearance and complexity of acquired surfaces. The PhD student will also take part in the experimental process (measurements and psycho-visual experiments). The complexity measurements calculated in the perceptual and physical domains will then be correlated with the results of the psycho-visual experiments. These results will be compared and shared with those obtained by the ANR project partners. They will also be promoted at international level in conjunction with the CIE (International Commission of Lightning).

Theme, Field :

- Signal and Image Processing
- Spectral Imaging
- Image Metrology

- Vision, Computer Vision

Objectives and context:

The ***Scealed*** ANR project provides the research context, involving the **Laplace** laboratory (Toulouse), **CEAC** (Lille), **SEPPIA** (Toulouse) and **XLIM**. The PhD student will work at XLIM as part of a team including PhD students working on related subjects, and a technical team responsible for manufacturing the technical components needed for experiments.

Scientific objectives include

- Measuring the textured (non-uniform) appearance of surfaces
    - Main focus of all approaches to appearance measurement.
    - Project specificity: link between perceptual and physical measurements, correlation with psycho-visual experiments.
- Measuring the spatiochromatic complexity of a surface
    - Complexity measurement is part of the non-uniform appearance measurements. It is also the only measurement that allows us to establish a correlation between the 3 domains of the project (physical, perceptual, psycho-visual).
    - Project specificity: link between perceptual and physical measurements, correlation with psycho-visual experiments
- Measurement of light quality
    - Current measurements are limited to comparison between uniform color zones (CRI, TM30-20...) or to are limited to spectral similarities
    - Project specificity: considering the spatial impact of a lighting system's loss of spectral quality

Method:

- Set up and participate in color and spectral acquisitions of non-uniform textiles (laboratory and theater conditions).
- Set up and take part in psychovisual experiments under theater conditions. Produce analysis results for correlation.
- Develop and validate digital attributes for measuring the non-uniform (textured) appearance of images in the physical and perceptual domains [2-5].
- Develop and validate numerical attributes for measuring complexity in physical and perceptual domains [1].
- Correlate the obtained results and participate in their analysis with the rest of the ANR project team.
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Complete subject description:

This thesis focuses on the measurements of the surface appearance complexity [2-5]. The measurement must be generic (independent of sensor characteristics). It must also be computable in the perceptual domain (colorimetry) as well as in the physical domain (photometry). The aim is to be able to correlate measurements made in these two domains.

In work carried out within the CIE [1], it was shown that a fractal measurement based on fractional Brownian motion met the formulation expectations. The aim of the thesis is to solve the various theoretical problems required to define generic and robust (control of uncertainties) approachs. Particular attention will be paid to defining references and ranges of standards.

In the context of the ANR ***Scealed***, the theoretical results will be applied to "*measuring the quality of light in the context of entertainment*". The research hypothesis is that the loss of spectral quality in

lighting translates visually into a loss of complexity in the textile observed (fabrics, skin, coverings, etc.). In [1], an initial study showed that the human visual system is sensitive to a differences in physical complexity, justifying the proposed construct.

Experimental validation will be based on measurements under real-life conditions: physical measurements (color, multi and hyperspectral) and psycho-visual experiments (observer responses to defined stimuli). These will be supplemented by measurements under laboratory conditions in Poitiers and Toulouse. Physical and perceptual complexity results will be compared and correlated. These results will then be correlated with those of the psycho-visual studies and surveys carried out by the ANR project partners.

Objectives for promoting the doctoral student's research work: dissemination, publication and confidentiality, intellectual property rights:

- 2 to 3 publications in A-rank international journals
    - In order to extend the possibilities of publication, it is planned to extend the theoretical results obtained in the more global context of spectral imagery, particularly satellite imagery ("remote sensing").
- 2 High-level international conferences
- Participation in specialized conferences on spectral imaging, color and perception
- Participation in CIE work on the themes of lighting quality, and measurement of non-uniform appearance (perceptual and physical domains).

Envisaged collaborations:

- Significant collaboration is expected with members of the Scealed project (meetings, knowledge sharing, exchanges, publications, etc.):
    - Georges Zissis' team, Lumière-Matière team, Laboratoire Laplace de l'Université de Toulouse, on spectral measurement aspects.
    - Véronique Perruchon's team, from the CEAC laboratory at the University of Lille, on psychovisual aspects.
    - Céline Caumon's team, from the SEPPIA laboratory at the University of Toulouse, on psychovisual aspects.
- With Hermine Chatoux
    - On measuring the textured (non-uniform) aspect of surfaces and measuring complexity
    - On links with the work of CIE Division 8

International scope :

- This work is part of a number of major international issues raised in particular by CIE division 1 (Vision and Colour), CIE division 2 (Physical Measurement of Light and radiation), CIE division 3 (Interior Environment and lighting design) and CIE division 8 (Image Technology).
- They are also part of the major challenges in the field of remote sensing.

Références bibliographiques :

1. N. Richard, ***Spatio-chromatic complexity : Definition and assessments***, TC 8-14 report, CIE, 2024 (in edition).
2. Hermine Chatoux, ***Prise en compte métrologique de la couleur dans un contexte de classification et d'indexation***, co-encadrement avec François Lecellier et Christine Fernandez-Maloigne, Octobre 2016-mai 2019, Maître de Conférences à Dijon.

3. Chu Rui-Jian, ***Texture features for hyperspectral Image Analysis***, co-encadrement à 70% avec Christine Fernandez-Maloigne, ANR DigiPi, Janvier 2019-Juin2022
4. R.J. Chu, N. Richard, H.Chatoux, C. Fernandez-Maloigne, J.Y. Hardeberg, ***Hyperspectral Texture Metrology Based on Joint Probability of Spectral and Spatial Distribution***, IEEE Transactions on Image Processing, Vol 30, https://doi.org/10.1109/TIP.2021.3071557, pp 4341-4356, 2021
5. R.J. Chu, N. Richard, H.Chatoux, C. Fernandez-Maloigne, J.Y. Hardeberg, ***GHOST: Gradient Histogram of Spectral Texture***, 11th Workshop on Hyperspectral Image and Signal Processing : evolution in remote sensing (WHISPERS), Amsterdam(NL), April 2021 (on line)