ERCIM "ALAIN BENSOUSSAN" FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Fereshteh Mirjalili
Nationality	Iranian
Name of the *Host Organisation*	NTNU, Norway
First Name / family name of the *Scientific Coordinator*	Jon Yngve Hardeberg
Period of the fellowship	01/10/2018 to 31/05/2020

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The ERCIM postdoctoral fellowship was carried out at the Norwegian Colour and Visual Computing Laboratory at the Department of Computer Science, NTNU, Norway. As a member of the group and beside my own research activities, I was entitled to attend the group's meetings, participate in several experimentations, and collaborate in research projects supervised by my colleagues in the department. I was also granted access to all the NTNU's facilities that are available for postdoctoral fellows.

The main research activities during the fellowship were associated with the ongoing TOPPFORSK FRIPRO project MUVApp (Measuring and Understanding Visual Appearance), at the Norwegian Colour and Visual Computing Laboratory, NTNU. The project aimed at developing new knowledge on how humans perceive the visual appearance of materials, objects, and scenes, and developing new methodologies for measuring and communicating visual appearance and appearance-related material and object properties.

Appearance of an object is the visual perception of that object, inclusive of size, shape, colour, texture, gloss, transparency, opacity, etc., separately or integrated. Appearance is the result of a series of complex interactions of incident light with an object, which is influenced by the composition of incident light, the optical characteristics of the object itself, and the human perception mechanism. These interactions modify the appearance of the object which can be subdivided into chromatic and geometric attributes. It is also possible to characterize the optical properties of materials by at least four subdivisions, namely colour, gloss, translucency, and surface texture.

The overall goal of the MUVApp project is to propose, optimize, and evaluate appearance models, which define relationship between physical measurements and perceptual appearance attributes (such as colour, gloss, translucency, and texture). Since this overall goal of the project is broad and needs a lot of research, the main focus of my research during the fellowship was studying the texture perception of materials. Understanding the visual perception of texture has a wide range of applications from computer science (image processing and image segmentation) to interior design. The findings of the first half of the research were presented as two papers i.e. [1] and [2] at the Twenty-seventh Color and Imaging Conference (CIC27).

The second half of the research was focused on finding the best quantitative representations of human texture perception, by the aid of image texture analysis techniques. The findings of this study are now being considered for submission to a peer reviewed journal i.e. paper [3]. I also had the opportunity to contribute to the related research work conducted by one of my colleagues at the department of computer science which led to another conference submission.

During the time I was working on this project, I had the chance to perform several psychophysical experiments and make myself even more familiar with psychophysical data collection and analysis techniques. I could also give a few talks in the workshops held at the Norwegian Colour and Visual Computing Laboratory.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

[1] Mirjalili, Fereshteh; Hardeberg, Jon Yngve, "Appearance perception of textiles: a tactile and visual texture study," Final program and proceedings of the Twenty-seventh Color and Imaging Conference (CIC27), Paris, France, October 2019.

Abstract: Texture analysis and characterization based on human perception has been continuously sought after by psychology and computer vision researchers. However, the fundamental question of how humans truly perceive texture still remains. In the present study, using a series of textile samples, the most important perceptual attributes people use to interpret and evaluate the texture properties of textiles were accumulated through the verbal description of texture by a group of participants. Smooth, soft, homogeneous, geometric variation, random, repeating, regular, color variation, strong, and complicated were ten of the most frequently used words by participants to describe texture. Since the participants were allowed to freely interact with the textiles, the accumulated texture properties are most likely a combination of visual and tactile information. Each individual texture attribute was rated by another group of participants via rank ordering. Analyzing the correlations between various texture attributes showed strong positive and negative correlations between some of the attributes. Principal component analysis on the rank ordering data indicated that there is a clear separation of perceptual texture attributes in terms of homogeneity and regularity on one hand, and non-homogeneity and randomness on the other hand.

[2] Gigilashvili, Davit; Mirjalili, Fereshteh; Hardeberg, Jon Yngve, "Illuminance impacts opacity perception of textile materials," Final program and proceedings of the Twenty-seventh Color and Imaging Conference (CIC27), Paris, France, October 2019.

Abstract: Opacity is an important appearance attribute in the textile industry. Obscuring power and the way textile samples block light can define product quality and customer satisfaction in the lingerie, shirting, and curtain industries. While the question whether opacity implies the complete absence of light transmission remains open, various factors can impact cues used for opacity assessment. We propose that perceived opacity has poor

consistency across various conditions, and it can be dramatically impacted by the presence of a high-illuminance light source. We have conducted psychophysical experiments asking human subjects to classify textile samples into opaque and non-opaque categories under different illumination conditions. We have observed interesting behavioral patterns and cues used for opacity assessment. Finally, we found obvious indications that the high-illuminance light source has a significant impact on opacity perception of some textile samples, and to model the impact based on material properties remains a promising direction for future work.

[3] Mirjalili, Fereshteh; Conni, Michele; Hardeberg, Jon Yngve, "Visual perception of texture complexity of textiles," Submitted paper.

Abstract: Complexity is one of the major attributes of the visual perception of texture. However, very little is known about how humans visually interpret texture complexity. A psychophysical experiment with ten participants was conducted to visually quantify the texture complexity of twenty-three textile fabrics, chosen from the HyTexila texture database. Several texture measures including pure color descriptors, co-occurrence matrix and Gabor features were obtained for images of the textiles in different color spaces. The relationship between the visually quantified texture complexity and the texture measures of images was investigated. Analyzing the relationships indicates that the standard deviation of the magnitude of images after filtering with appropriately designed Gabor filters, as texture feature, could be a good candidate for objective quantification of visual texture complexity. Moreover, the highest correlations between visual data and texture measures were always obtained for the luminance channels of color spaces suggesting that variation in luminance or luminance contrast plays the crucial role in creating the so-called visual texture complexity.

[4] Tian, Yuan; Thomas, Jean-Baptiste; Mirjalili, Fereshteh

Abstract: We investigated the impact of individual observer color matching functions (CMF) on simulated texture features. Our hypothesis is that most people perceive texture in a similar manner, thus a texture indicator that is least dependent on human individual vision would be most likely a potential fit to visually perceived texture. To this end, the following strategy was implemented: Hyper-spectral images were converted into XYZ images for individual observer CMFs, estimated by an individual observer colorimetric model. Contrast sensitivity function (CSF) filtering was applied to the XYZ images for visual simulation. The texture features were extracted from the filtered images. Finally, the difference between the texture features computed for each observer were analyzed.
We used the HyTexiLa reflectance image dataset by Khan et al. [1], that includes 112 images of four material classes, namely textile, wood, stone and food, covering a wavelength range from 400 to 1000 nm with 3.19 nm intervals. The individual observer CMFs were generated using the color vision model proposed by Asano et al. [2]. Their dataset includes 151 individual CMFs obtained as a result of a series of color matching experiments performed by 151 color-normal observers. The proposed model predicts individual cone fundamental, lms-CMF, as a function of person's age and some physiological parameters such as lens and macular pigment density. Each Individual lms-CMF was converted into the corresponding xyz-CMF by a linear transform obtained from a linear regression between the CIE 1964 standard colorimetric observer and the average lms-CMFs. The reflectance images were subsequently converted into XYZ images using the obtained xyz-CMFs.
To perform CSF filtering following the method proposed by Pedersen and Farup [3], the reflectance images were first converted into individual observer XYZ images using the

obtained individual xyz-CMFs. The XYZ images were then converted into RGB images by linear transformation. The individual RGB images were finally converted into the corresponding individual observer YCbCr images using a specific set of RGB stimulus. The variability of the CMFs between individual observers is assumed to be maintained in the YCbCr color space. Finally, the contrast masking was applied on the YCbCr images to simulate the viewing distances of approximately 0.5 and 2 meters.
Two methods to compute texture features are implemented, one method to extract texture features from Y channel, and the other from all three channels of the individual observer YCbCr CSF filtered images. In order to test the hypothesis, a comparison of the texture features is implemented between two observer groups, one with lower RMSE in CMFs from the average observer, and the other with higher RMSE in CMFs. In texture feature hyperspaces, the volume ratio between the two groups' feature vector clouds indicates how individual observers have similar texture features.

[1] H. A. Khan, S. Mihoubi, B. Mathon, J. B. Thomas, and J. Y. Hardeberg, "HyTexiLa: High resolution visible and near infrared hyperspectral texture images," Sensors, vol. 18, no. 7, pp. 1–30, 2018.
[2] Y. Asano, M. D. Fairchild, and L. Blondé, "Individual colorimetric observer model," PLoS One, vol. 11, no. 2, pp. 1–19, 2016.
[3] M. Pedersen and I. Farup, "Simulation of image detail visibility using contrast sensitivity functions and wavelets," Proc. - IS&T/SID Color Imaging Conf., pp. 70–75, 2012.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. Scientific conference: Twenty-seventh Color and Imaging Conference (CIC27), Paris, France, 21-25 October 2019.
2. Workshop: Bidirectional Reflectance Definitions (BiRD) project research activities, Alto University, Finland, November 2019.
2. Workshop: ApPEARS-ITN project kick off, Norwegian Colour and Visual Computing Laboratory, NTNU, Norway, April 2019.
3. Workshop: CHANGE-ITN project kick off, Norwegian Colour and Visual Computing Laboratory, NTNU, Norway, May 2019.
4. Workshop: MUVApp project research activities, Norwegian Colour and Visual Computing Laboratory, NTNU, Norway, June 2019.
5. Workshop: MUVApp project research activities, Norwegian Colour and Visual Computing Laboratory, NTNU, Norway, October 2019.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Due to the inevitable lockdowns after spreading the Covid_19, the ERCIM partners whose research activities were in line with my research were unfortunately unable to accept me. Therefore, I did not have a chance to complete my Research Exchange Programme (REP) during my fellowship.