Scientific Report

First name / Family name	Muhammad Safdar
Nationality	Pakistani
Name of the *Host Organisation*	NTNU, Norway
First Name / family name of the *Scientific Coordinator*	Jon Yngve Hardeberg
Period of the fellowship	01/04/2018 to 31/07/2019

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

I worked on development of a colour appearance model based on a uniform colour space I developed during my PhD studies. The objective was to develop a computationally simple and comprehensive colour appearance model with an integrated uniform colour space. The new colour appearance model includes ten different colour attributes: lightness, brightness, chroma, colourfulness, hue, hue composition, saturation, vividness, whiteness and blackness compared with first seven attributes included in the state-of-the-art . The performance of the newly developed colour appearance model was compared with the state-of-the-art CIE colour appearance model CIECAM02 and its revised version CAM16. The new colour appearance model gave either better or at least similar performance to predict experimental data of ten different colour scales. The new colour appearance model is also computationally simple and comprehensive compared with state-of-the-art.

Secondly, I worked on a project on colour consistency in collaboration with the CIE TC8-16. In this project, a perceptual study was conducted to evaluate consistency of color appearance based on subjective colour difference. The twofold objective of the experiment was: (1) to determine the degree of agreement between observers on consistency of colour reproduction between different colour gamuts, and (2) to obtain data on the rendering methods that maximize consistent colour reproduction. Three different print media were simulated on a calibrated display and magnitude estimation method was used to scale

image colour difference. Six source images and three print media were selected from the CIE TC8-16 recommended stimuli and candidate profiles, respectively. Source images after transformation to the print media were manipulated in CIELAB space and white border was added for adaptation of the media. Coefficient of correlation and STRESS were computed between observer magnitudes of the colour difference, between a source image and a set of reproductions, and predictions of the CIE standard colour difference formula.

Thirdly, I supervised an MS student who conducted an experiment on colour image quality. In this experiment, a perceptual study was conducted to enhance colour image quality in terms of naturalness and preference using perceptual scales of saturation and vividness. Saturation scale has been extensively used for this purpose while vividness has been little used. Moreover, no such study has used a perceptual scale for vividness but hypothetical formula based on CIELAB colour space. We used perceptual scales of a recently developed colour appearance model based on $J_za_zb_z$ uniform colour space. A twofold aim of the study was (i) to test performance of recently developed perceptual scales of saturation and vividness compared with previously used hypothetical models and (ii) to compare performance and chose one of saturation and vividness scales for colour image enhancement in future. Test images were first transformed to $J_za_zb_z$ colour space and their saturation and vividness were then decreased or increased to obtain 6 different variants of the image. Categorical judgment method was used to judge preference and naturalness of different variants of the test images and results are reported in this paper.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Papers accepted/published:
1. Muhammad Safdar, JY Hardeberg, YJ Kim, MR Luo, "A Colour Appearance Model based on Jzazbz Colour Space," The 26th Color and Imaging Conference, Vancouver, Canda, Nov 12-16, 2018.
2. Muhammad Safdar, Noémie Pozzera, JY Hardeberg, "Colour Image Enhancement using Perceptual Saturation andVividness," Accpeted in The 27th Color and Imaging Conference, Paris, France, Oct 21-25, 2019.

Papers at submission stage:
1. Muhammad Safdar, JY Hardeberg, MR Luo, "Measuring Spectral Image using RGB Digital Camera," JIST (Submission stage).
2. Muhammad Safdar, JY Hardeberg, MR Luo, "Towards a Colour Appearance Model for High Dynamic Range and Wide gamut Imagery," Applied Optics (Submission stage).

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I attended the 9th Colour and Visual Computing Symposium 2018 (CVCS 2018) September 19-20, 2018, Gjøvik, Norway.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I spent a week at Fraunhofer IGD in Darmstadt, Germany with Professor Philipp Urban. I worked on my paper on colour image quality enhance by varying perceptual vividness and whiteness.