Re-Coloring of Grayscale Images: Models with Aesthetic and Golden Proportions

Artyom M. Grigoryan and **Sos S. Agaian**

Department of Electrical and Computer Engineering
The University of Texas at San Antonio, San Antonio, Texas USA
and
Computer Science Department, College of Staten Island and the Graduate Center, Staten Island, NY, USA

amgrigoryan@utsa.edu sos.agaian@csi.cuny.edu

April 2018, SPIE

OUTLINE

- Introduction
- Grayscale-to-color transformations
- 6 Models of Color Images with Gold Ratio
  Re-coloring from Grays
  Re-coloring from Intensity
- 6 Models of Color Images with Aesthetic Ratio
  Re-coloring from Grays
  Re-coloring from Intensity
- Examples with color images and painting
- Examples with grayscale images
- Summary
- References

Abstract

- The problem of color image composition from original grayscale images is considered. A few models are proposed and analyzed, which are based on the observation done on many color images that <u>in average a proportion exists between primary colors in images</u>.
- Re-coloring of grayscale images are performed in the RGB color model and the Golden, Silver, Aesthetic ratios and other rules of proportions are considered between the primary colors. The gray is used as the main color to be map into the three colors at each pixel.
- A parameterized model with the given ratio of re-coloring images is also described. The coloring of grayscale image allows us to apply the powerful tool of quaternion imaging for image enhancement and facial imaging.

Introduction

- The goal of this paper is to propose a few models for coloring images. Our assumption is based on the observation done on many color images that in average a certain proportion exists between primary colors in images.
- The Golden, Silver, Aesthetic, and other ratios were used in architecture and art from the ancient. We consider that the common principles of construction of the nature objects can be applied to real images, when analyzing the brightness of primary colors at each pixel of images.
- The Golden and Aesthetic ratios and other rules of proportions can be considered between colors. The concept of the three-color proportion is defined based on this ratio and color image is calculated by using the gray as the main color to be map into the three colors at each pixel.

GRAYSCALE TO COLOR IMAGE TRANSFORMS

We consider a color image $f_{n,m}$ in the RGB model, when the color image $f_{n,m}$ has three components, red, green, and blue colors,

$$f_{n,m} = \left(r_{n,m}, g_{n,m}, b_{n,m}\right), n = 0:(N-1), m = 0:(M-1).$$

The grayscale image is defined as the average of colors

$$a_{n,m} = \left(r_{n,m} + g_{n,m} + b_{n,m}\right)/3.$$

(a)

(b)

Figure 1. (a) The original color image and (b) the grayscale image.

Models of Gray-to-Color Images

In coloring the grayscale image, it can be assumed that the relation between the colors and grays is described by some proportions

$$r_{n,m} = \alpha a_{n,m}, \qquad g_{n,m} = \beta a_{n,m}, \qquad b_{n,m} = \gamma a_{n,m},$$

where $\alpha, \beta,$ and γ are constants.

We consider a few models for coloring grayscale images, that are based on the well known numbers; the golden ratio, $\Psi = 1.6180$ and Aesthetic ratio ψ=1.322.

Model 1: The main color is the gray, and the three color components of a new image $f'_{n,m}$ are calculated by

$$r'_{n,m} = 1 \times a_{n,m}, \qquad g'_{n,m} = \sqrt{\Psi} \times a_{n,m}, \qquad b'_{n,m} = \Psi \times a_{n,m}.$$

at each pixel (n, m). This model is called the **(1,$\sqrt{\boldsymbol{\Psi}}, \boldsymbol{\Psi}$)-model**.

(a) (b) (c) (d)

Figure 4: (a) The color image (from "http://www.abcgallery.com/"), the grayscale image, and the images (c) in the $(\sqrt{\Psi},\Psi,1)$- and (d) $(\Psi,\sqrt{\Psi},1)$-models.

Model 2: The main color is the gray, and the three color components of a new image $f'_{n,m}$ are calculated by

$$r'_{n,m} = 1 \times a_{n,m}, \qquad g'_{n,m} = \Psi \times a_{n,m}, \qquad b'_{n,m} = \sqrt{\Psi} \times a_{n,m},$$

at each pixel (n, m). This model is called the **$(1,\Psi,\sqrt{\Psi})$-model**.

Model 3: The main color is the gray, and the three color components of a new image $f'_{n,m}$ are calculated by

$$r'_{n,m} = \sqrt{\Psi} \times a_{n,m}, \qquad g'_{n,m} = 1 \times a_{n,m}, \qquad b'_{n,m} = \Psi \times a_{n,m},$$

at each pixel (n, m). This model is called the **($\sqrt{\boldsymbol{\Psi}}$,1,$\boldsymbol{\Psi}$)-model**.

Model 4: The main color is the gray, and the three color components of a new image $f'_{n,m}$ are calculated by

$$r'_{n,m} = \Psi \times a_{n,m}, \qquad g'_{n,m} = 1 \times a_{n,m}, \qquad b'_{n,m} = \sqrt{\Psi} \times a_{n,m},$$

at each pixel (n, m). This model is called the **($\boldsymbol{\Psi}, \mathbf{1}, \sqrt{\boldsymbol{\Psi}}$)-model**.

The $(\sqrt{\Psi}, \Psi, 1)$- and $(\Psi, \sqrt{\Psi}, 1)$-models are defined similarly.

Such triplets of colors $(r'_{n,m}, g'_{n,m}, b'_{n,m})$ are called ***the gold colors***.

In the range of [0,255], there are 157 integer triplets in each of these six models; $255/\Psi = 157.5987$.

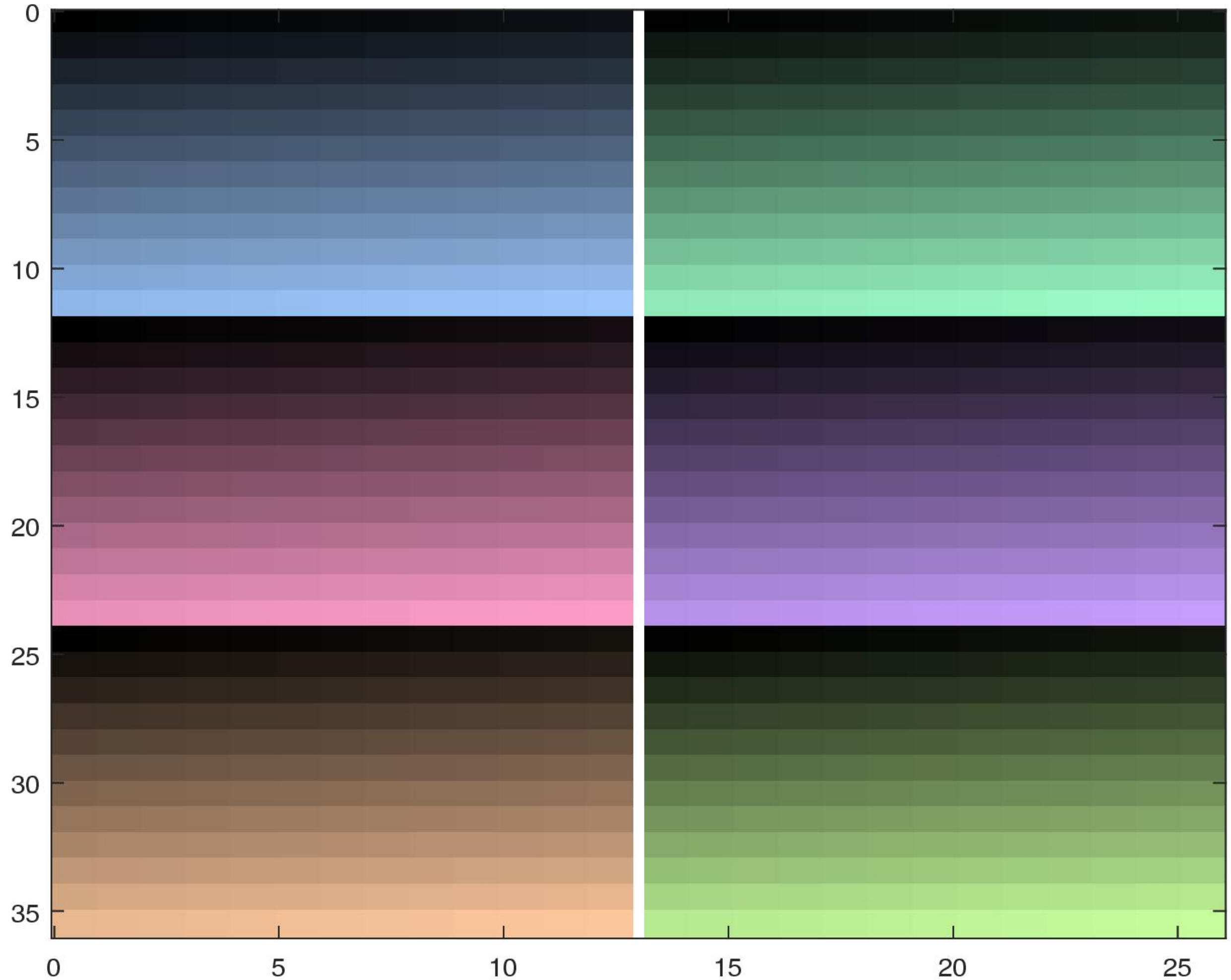

Figure 3. 936 golden colors, when the range of each color component is [0,255].

Figure 5. (a) The original image ("http://www.abcgallery.com/"), (b) the grayscale image, and (c)-(h) the images calculated in the $(\sqrt{\Psi}, \Psi, 1)$, $(\Psi, \sqrt{\Psi}, 1)$, $(1, \sqrt{\Psi}, \Psi)$, $(1, \Psi, \sqrt{\Psi})$, $(\sqrt{\Psi}, 1, \Psi)$, and $(\Psi, 1, \sqrt{\Psi})$-models.

The 744 × 562 Image "vangogh81.jpg" of Van Gogh's Painting

The color images calculated in the models: $(\sqrt{\Psi},\Psi,1)$, $(\Psi,\sqrt{\Psi},1)$, $(1,\sqrt{\Psi},\Psi)$, $\left(1,\Psi,\sqrt{\Psi}\right)$, $\left(\sqrt{\Psi},1,\Psi\right)$, and $(\Psi,1,\sqrt{\Psi})$.

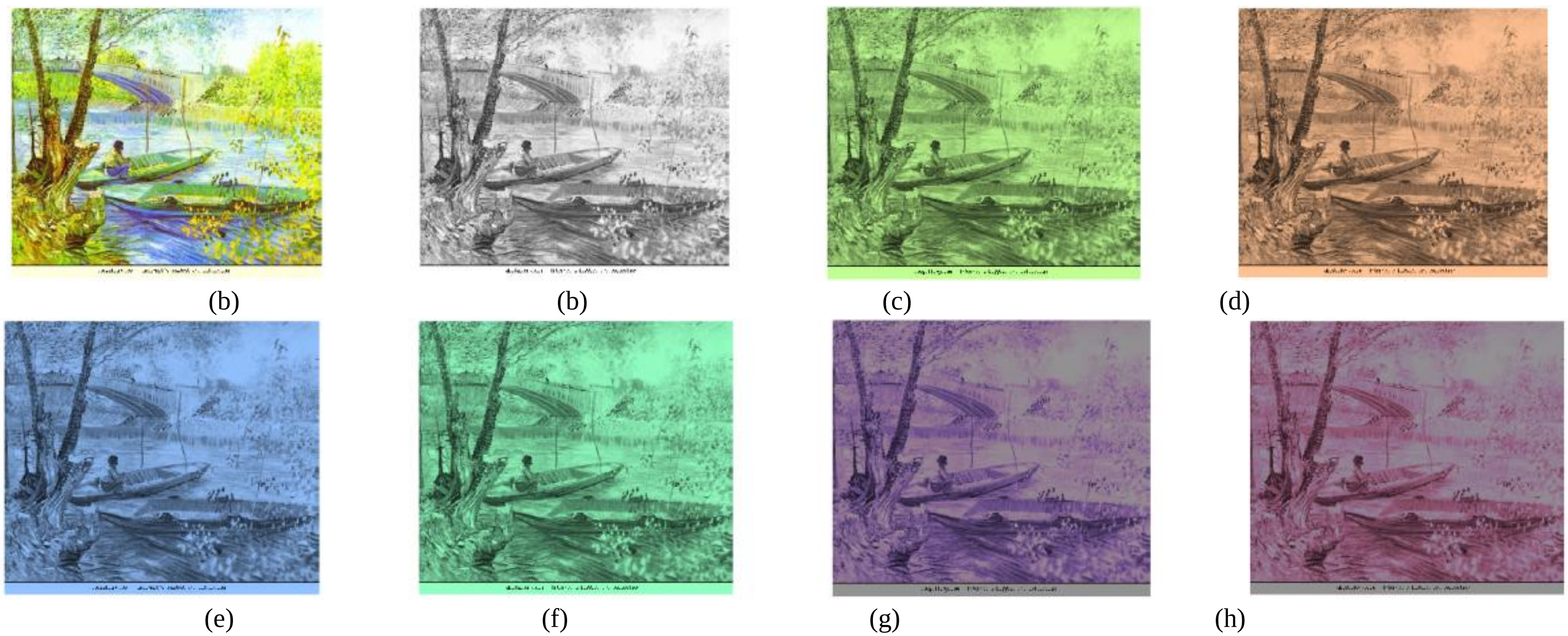

Figure 6. (a) The original image (from "http://www.abcgallery.com/"), (b) the grayscale image, and (c)-(h) the images calculated in the $(\sqrt{\Psi},\Psi,1)$, $(\Psi,\sqrt{\Psi},1)$, $(1,\sqrt{\Psi},\Psi)$, $\left(1,\Psi,\sqrt{\Psi}\right)$, $\left(\sqrt{\Psi},1,\Psi\right)$, and $(\Psi,1,\sqrt{\Psi})$-models, respectively.

Models with Intensity

In all six models described above, we can consider the grayscale image presenting the intensity

$$i_{n,m} = 0.3r_{n,m} + 0.59g_{n,m} + 0.11b_{n,m}.$$

Model 1: The main color is the intensity, and the three color components of a new image $f'_{n,m}$ are calculated by

$$r'_{n,m} = 1 \times i_{n,m}, \qquad g'_{n,m} = \sqrt{\Psi} \times i_{n,m}, \qquad b'_{n,m} = \Psi \times i_{n,m},$$

at each pixel (n, m). This is the **(1,$\sqrt{\boldsymbol{\Psi}}, \boldsymbol{\Psi}$)-model** by intensity.

Other five models of re-coloring by intensity are defined in a similar way, by substituting $a_{n,m}$ by $i_{n,m}$.

The Color Image “leonardo9.jpg” and the Intensity Image

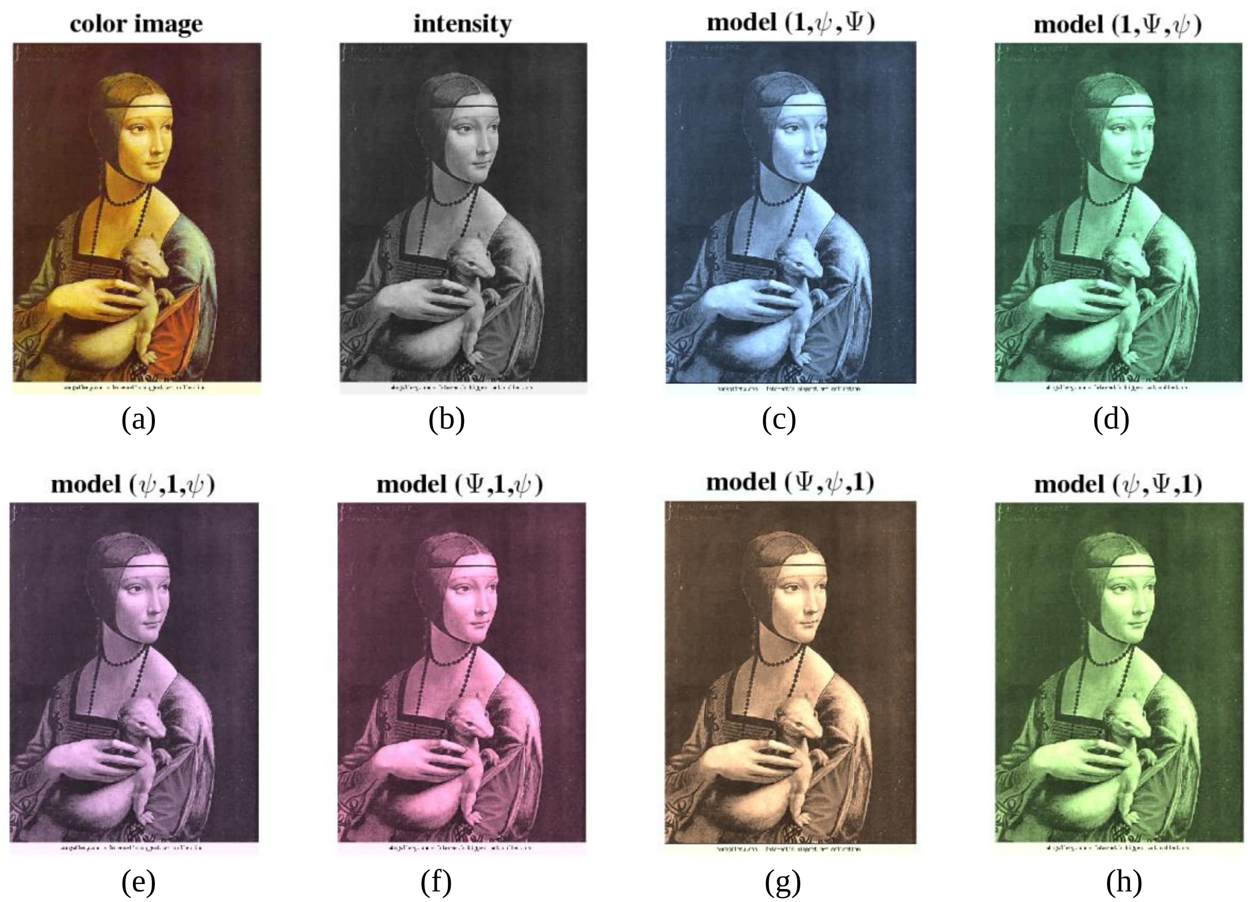

Figure 7. (a) The image (from “http://www.abcgallery.com/”), (b) the intensity, and (c)-(h) the images calculated in the $(1,\sqrt{\Psi},\Psi)$, $(1,\Psi,\sqrt{\Psi})$, $(\sqrt{\Psi},1,\sqrt{\Psi})$, $(\Psi,1,\sqrt{\Psi})$, $(\sqrt{\Psi},\Psi,1)$, and $(\Psi,\sqrt{\Psi},1)$-models by intensity, respectively.

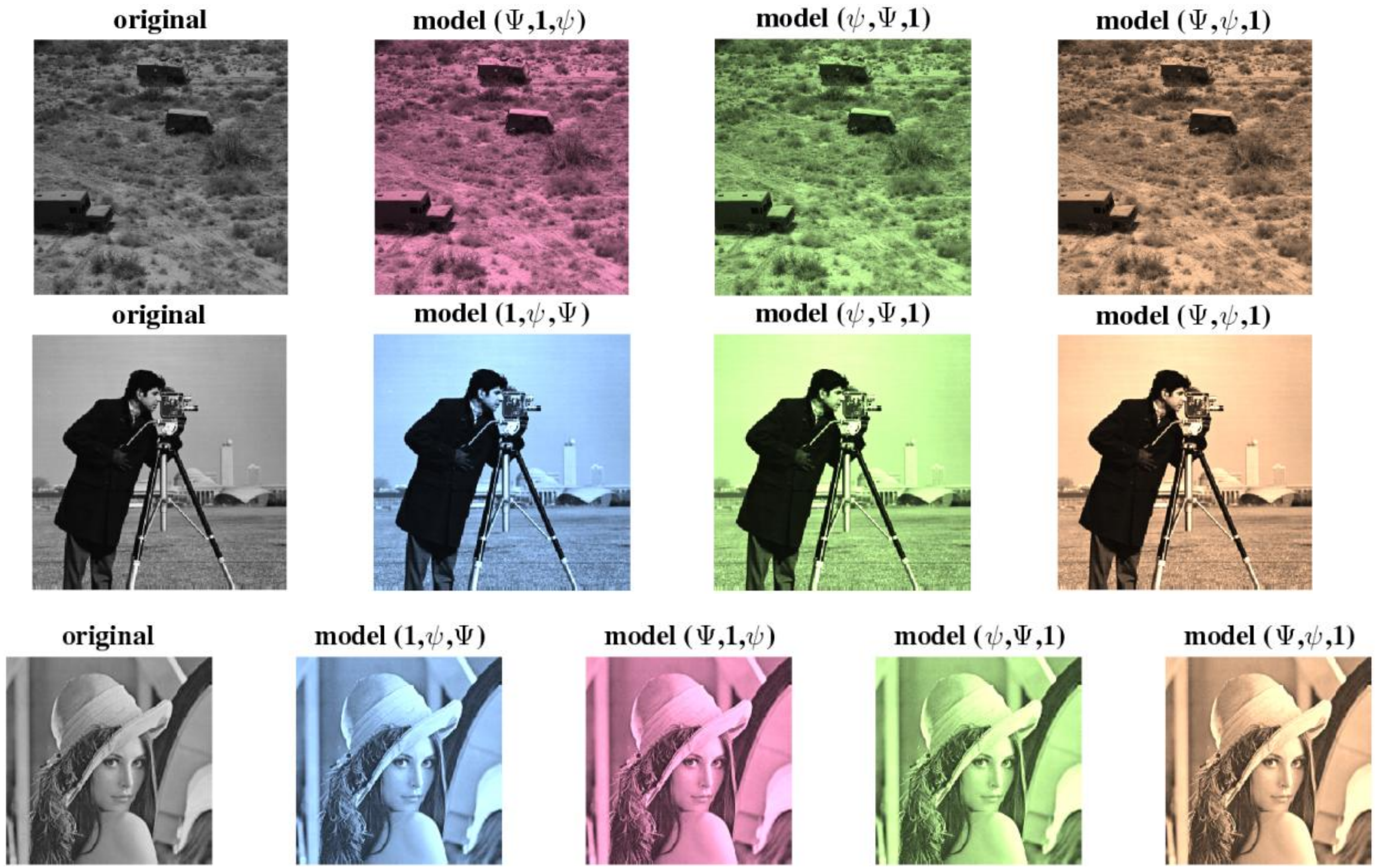

Figure 8. Grayscale images and the color images calculated in the $(1,\sqrt{\Psi},\Psi)$, $(\Psi,1,\sqrt{\Psi})$, $(\sqrt{\Psi},\Psi,1)$, and $(\Psi,\sqrt{\Psi},1)$-models.

MODELS WITH AESTHETIC RATIO 1.322

The Aesthetic ratio $\psi = 1.322$ and its square $\psi^2 = 1.7477$.

Model A1: The main color is the gray, and the three color components of a new image $f'_{n,m}$ are calculated as

$$r'_{n,m} = 1 \times a_{n,m}, \qquad g'_{n,m} = \psi \times a_{n,m}, \qquad b'_{n,m} = \psi^2 \times a_{n,m}.$$

This is the **(1,$\boldsymbol{\psi}, \boldsymbol{\psi^2}$)-model** by gray. Other five models of re-coloring are defined in a similar way.

Model I1: The main color is the intensity, and the three color components of a new image $f'_{n,m}$ are calculated as

$$r'_{n,m} = 1 \times i_{n,m}, \; g'_{n,m} = \psi \times i_{n,m}, \; b'_{n,m} = \psi^2 \times i_{n,m}.$$

This is the **(1,$\boldsymbol{\psi}, \boldsymbol{\psi^2}$)-model** by intensity.

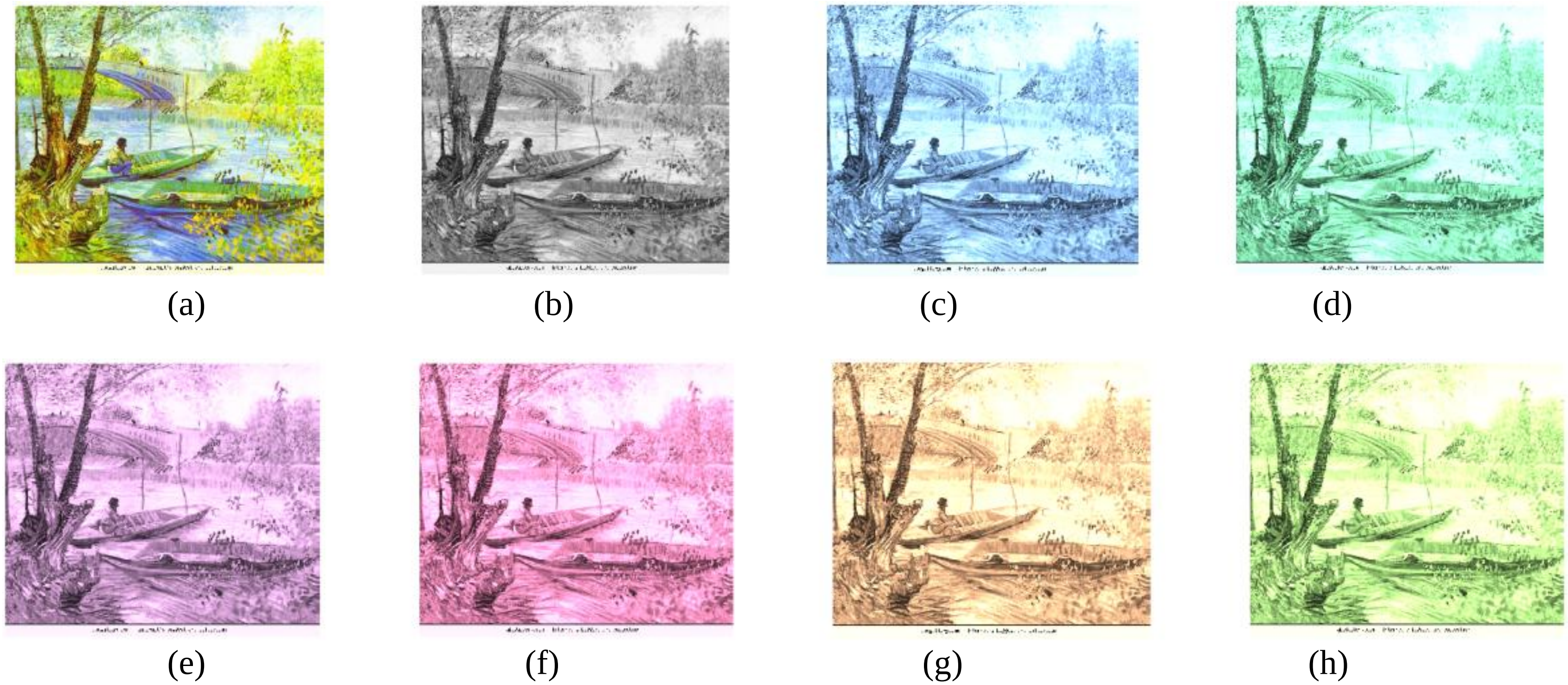

Figure 9: (a) The original color image (from "http://www.abcgallery.com/"), (b) the intensity image, and (c)-(h) the color images calculated in the $(1, \psi, \psi^2)$, $(1, \psi^2, \psi)$, $(\psi, 1, \psi^2)$, $(\psi^2, 1, \psi)$, $(\psi, \psi^2, 1)$, and $(\psi^2, \psi, 1)$-models by intensity, respectively.

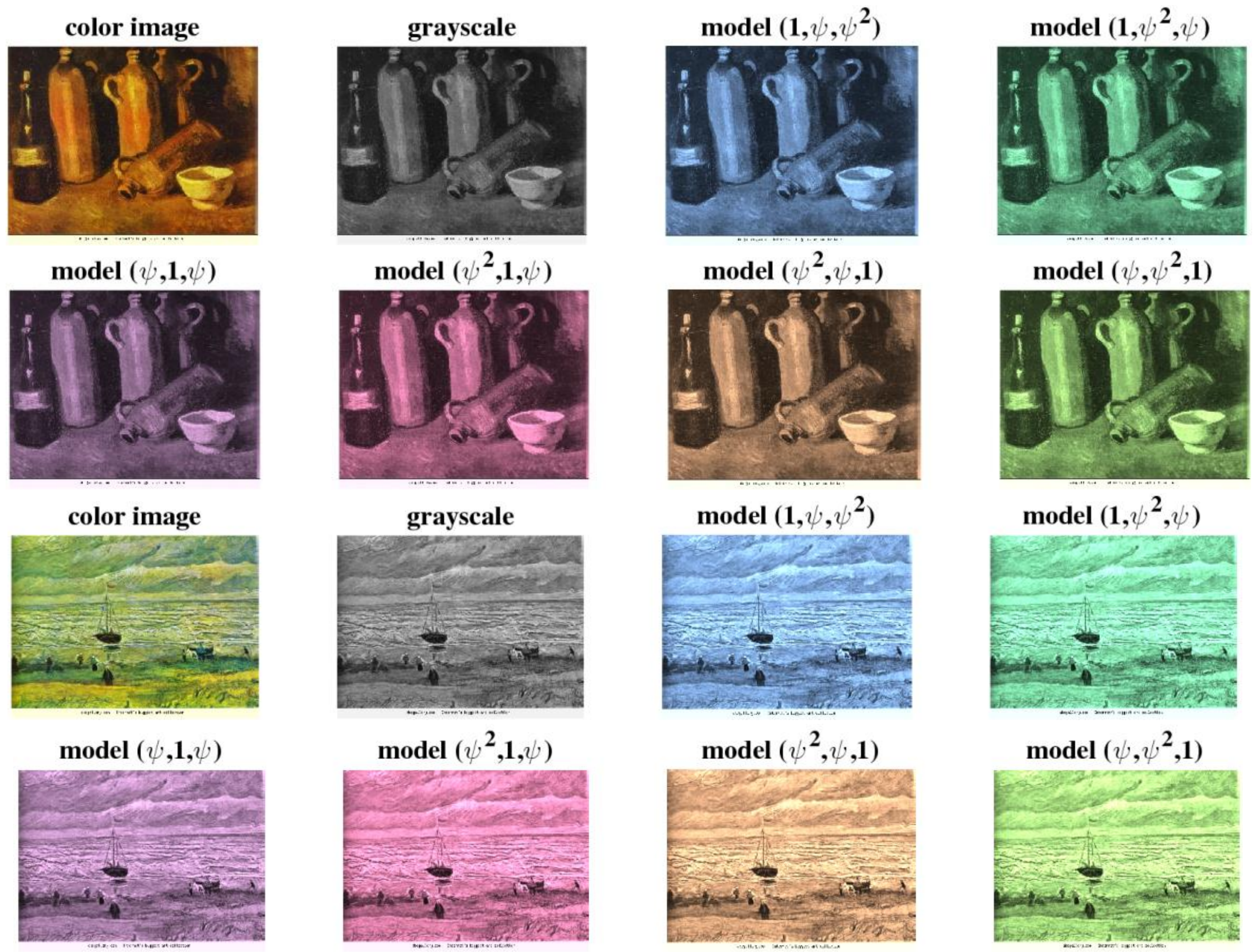

Figure 10: Original images (from "http://www.abcgallery.com/"), the intensity images and the images calculated in the $(1,\psi,\psi^2)$, $(1,\psi^2,\psi)$, $(\psi,1,\psi)$, $(\psi^2,1,\psi)$, $(\psi^2,\psi,1)$, and $(\psi,\psi^2,1)$-models by intensity.

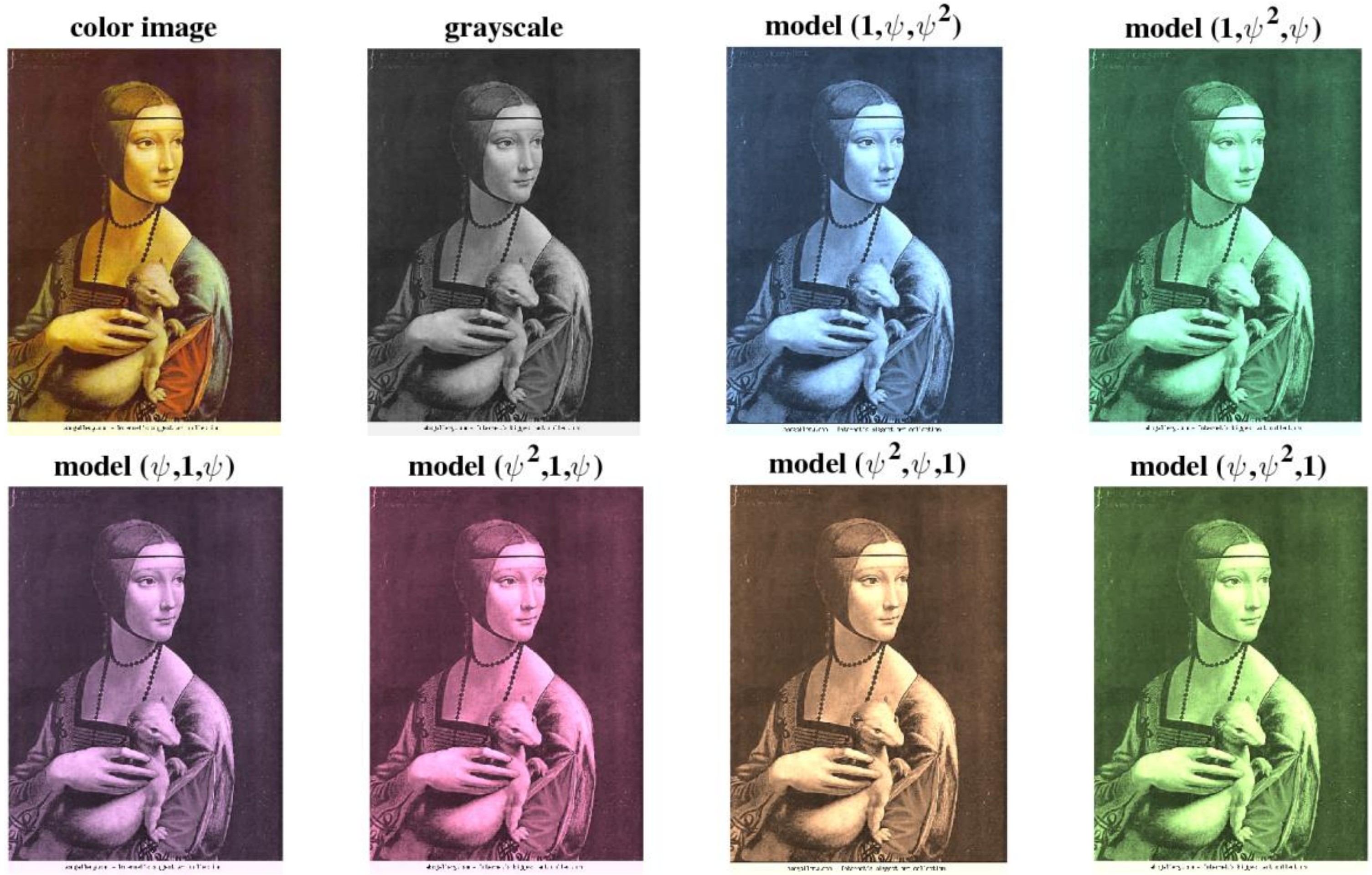

Figure 11: The original image (from "http://www.abcgallery.com/"), the intensity image, and the images calculated in the $(1,\psi,\psi^2)$, $(1,\psi^2,\psi)$, $(\psi,1,\psi)$, $(\psi^2,1,\psi)$, $(\psi^2,\psi,1)$, and $(\psi,\psi^2,1)$-models by intensity image.

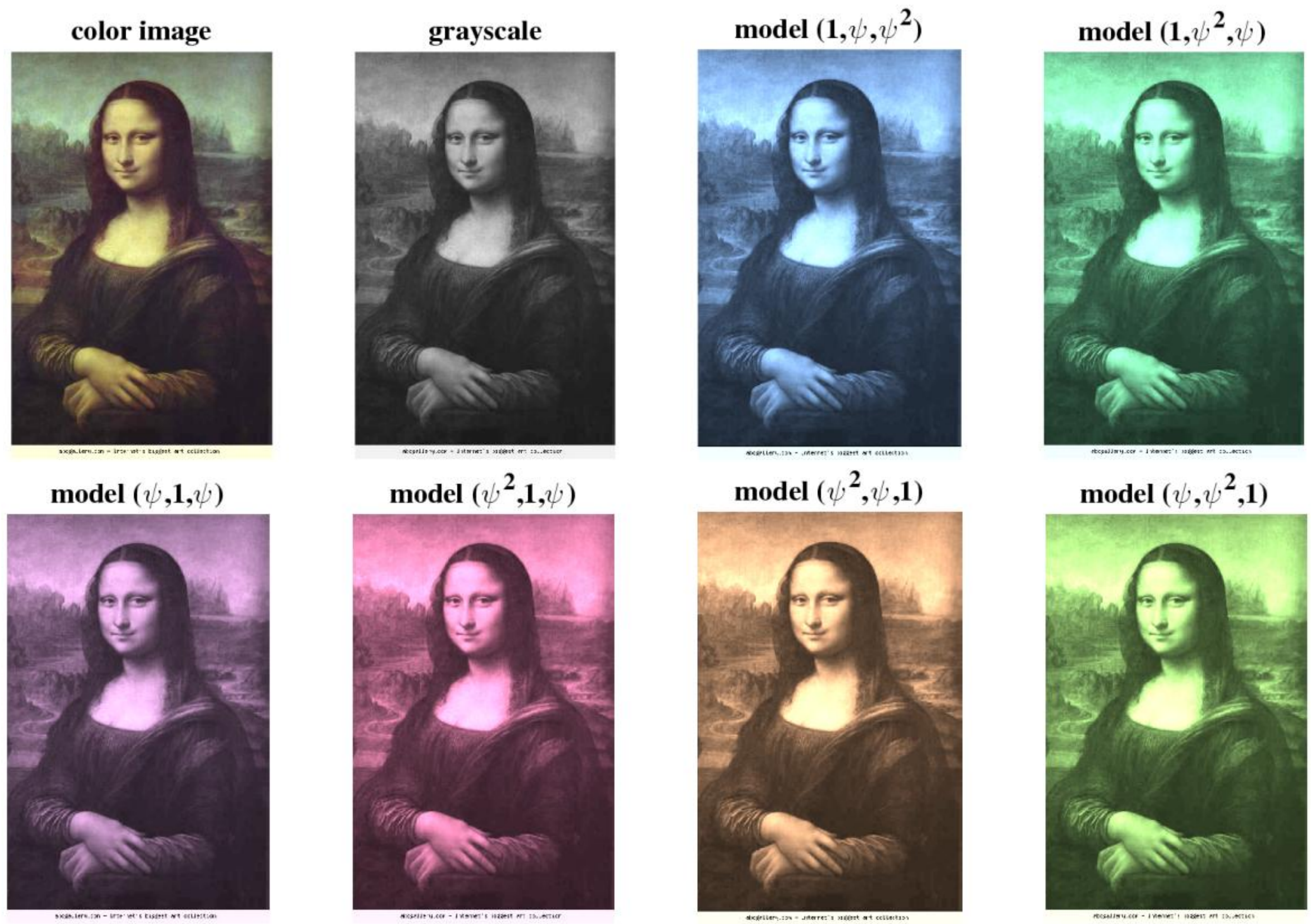

Figure 12: The original image (from "http://www.abcgallery.com/"), the intensity image, and the images calculated in the $(1,\psi,\psi^2)$, $(1,\psi^2,\psi)$, $(\psi,1,\psi)$, $(\psi^2,1,\psi)$, $(\psi^2,\psi,1)$, and $(\psi,\psi^2,1)$-models by intensity image.

Summary

In this paper, we describe new models of composing, or coloring the image from the grayscale or luminance images by using different models that are based on assumption that the colors of the image in the RGB model have proportions. For such proportions, the rule of the golden ratio is considered. The models based on the aesthetic ratio are also described and results of coloring images from the gray and luminance are illustrated.

References

1. A. Stakhov, “The golden section and modern harmony mathematics,” in book: Applications of Fibonacci Numbers,” 7, 393-399, Springer Netherlands (1998).
2. Sarkis S. Agaian, J.T. Gill III, “The extended golden section and time series analysis,” Frontiers in Signal Processing, 1(2), 67–80 (2017).
3. S. Bradley, “A geometric connection between generalized Fibonacci sequences and nearly golden sections,” The Fibonacci Quarterly, 38(2) 174–180 (1999)
4. A. van Zanten, “The golden ratio in the arts of painting, building and mathematic,” Nieuw Arch. Wisk., 17(2), 229–245 (1999).
5. A. Olariu, “Golden section and the art of painting,” National Institute for Physics and Nuclear Engineering, 1–4 (1999).