Analysing the Colours of the Virtual Reality Museums' Picture

Cecília Sik-Lányi, János Schanda

University of Pannonia, Egyetem u. 10, H-8200 Veszprém, Hungary
e-mail: lanyi@almos.uni-pannon.hu, schanda@vision.uni-pannon.hu

Abstract: Showing the works of famous artists to students is a fundamental task in order to teach fine art history. Images found on the Internet are a major source for such pictures that can replace older albums of fine art collections. The question arises as to how far one can rely on the colour quality of the images displayed on the Internet, and as to whether it is worthwhile to put much effort into the colour correct presentation on the receiving side. Images have been collected both from museums' publications and from the Internet, and some critical areas of the images have been colorimetrically evaluated. From these comparisons one can conclude that at present the distributors of the images do not pay enough attention to putting colour-correct images onto the Internet.

Keywords: colour; virtual reality; museum

1 Introduction

1.1 Background

Teaching fine art history without showing the masterpieces of past centuries is difficult. Unfortunately, it is impossible to take classes to all the major museums around the world to show the originals of the masterpieces to the students. Some fifty years ago, the art teacher had to rely on printed books of reproductions and had to use an epidiascope to show the pictures in the class. Then came the time of slides, and one was happy with the better colour quality of these. But slides fade, and after about ten years the colours become distorted. In recent years digital storage and reproduction via highly sophisticated projectors have become available, and one would hope that with proper colour management the perceived colours of the originals could be shown.

At the same time museums have started to archive the artifacts of their masterpieces in digital form, and more and more images are becoming available on the Internet. The pictures of the original images are taken by experts using

sophisticated high-end camera systems and illumination equipment to provide artefacts where the colours come near to the original ones [1]. Colour characterization of high-end digital cameras can yield digital images that hold most of the features of the original [2]. Digital restoration techniques can even help in rejuvenating faded paintings [3]. The recent technique of multi- (or hyper-) spectral image taking provides the opportunity to consider the reflectance spectra of the pigments the artist used [4]. This enables even transformations when looking at the pictures under different illuminants.

Despite all that hard work, the artefacts reproduced on the Internet often show remarkable differences if downloaded from different databases. In the present study, our main endeavour is to show the size of the colour differences one has to count on in reality.

As we will see, to take full advantage of present-day colorimetric capabilities, the providers of digital museum artefacts should supply more detailed metadata information, because otherwise, any further work by the user is only guess-work.

1.2 Colorimetric Fundamentals and Measurements

Pictures on the Internet are most often encoded using the IEC recommended sRGB encoding [5]; for further details and other encodings see e.g. [6], [7]. This encoding assumes standard RGB primaries (standardized RGB phosphors of CRT monitors) and a standard light intensity – digital value interrelationship, the so called gamma curve.

As every camera and every piece of reproducing equipment (monitor, projector, printer) have different encodings, it is usual to transform from the native colour space into a device independent colour space, the CIE recommended XYZ or L^*, a^*, b^* (or CIELAB) space [8], [9]. The latter one has the advantage that it provides reasonably uniform colour scales in lightness (L^*) and chroma (C_{ab}^*) and gives more or less equidistant scaling along the hue circle (h_{ab}^*). Figure 1 shows the co-ordinates of the CIELAB colour space.

The L^* coordinate goes from black ($L^* = 0$) to white $L^* = 100$), the positive a^* axis shows approximately into the red direction, the negative into the green direction, positive b^* represents yellow, negative b^* blue.

The h_{ab}^* hue angle is constructed as the arc tangent of b^*/a^*. Thus orange colours have arctg(b^*/a^*) values between 0° and 90°. Colours ranging in hue between yellow and green have hue angles between 90° and 180°, those between green and blue range between 180° and 270°, while purple colours might have hue angles between 270° and 360°.

The C_{ab}^* CIE chroma describes how vivid the colour is; colours with small chroma values are pale, greyish hues; strong, vivid hues have high chroma values.

In the evaluation of the different artefacts the L^* lightness value, the a^* and b^* co-ordinates, and also the h_{ab}^* hue-angle and the C_{ab}^* chroma information will be provided. Colour differences in these colour co-ordinates are: just noticeable if the colour differences as Euclidian distance between the L^*, a^*, b^* co-ordinates (ΔE^*)of the two colours to be compared are of the order of one to two units. Rich and co-workers [10] reported on the possibility of simulating surface colours on a CRT monitor within a $\Delta E_{ab}^* = 5$ range, although they admit that the usual reproduction differences are in the 6 to 12 ΔE_{ab}^* units range.

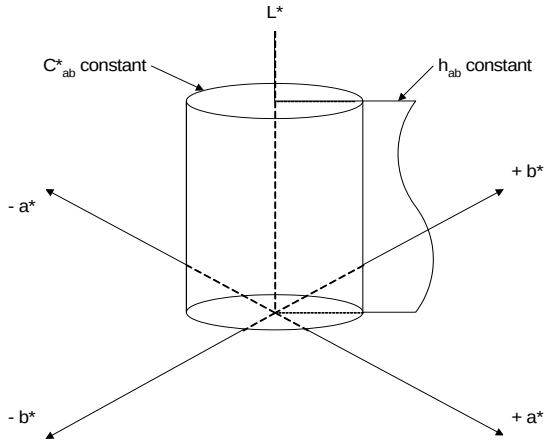

Figure 1
Coordinates of the CIE L^*, a^*, b^* colour system, called also CIELAB space

Measurements were performed partly using a Gretag Macbeth i1 spectrophotometer with a BabelColor software extension[1], partly – for some of the Internet artefacts – by loading the pictures into Adobe Potoshop®, using the eye-drop facility of the program and setting the colour management of the Photoshop to sRGB.

2 Examples of Colour Differences of Artefacts of the Same Pictures in Different Databases

The following examples are a non-exhaustive sample of a few pictures where artefacts of the same picture from different databases were found. Our intention was to show how large colour differences might be found on the Internet. In some cases we compared these with printed copies of the given picture as well. We have

[1] Thanks are due to Dr. Danny Pascale for helping our work with this software.

to stress that this investigation was conducted only on digital and printed artefacts, and we had no access to the original paintings, thus we had no information on the colour difference of one or the other artefact compared with the original.

2.1 Four Paintings by Leonardo da Vinci

As is well-known, Leonardo made at least two versions of the subject "Madonna/Virgin of the Rocks". The first one is a picture kept in the Louvre, Paris, and the latter one is in the National Gallery, London. As the subject of both paintings are very similar, it seemed to be worth not only investigating how different the coloration of the reproductions of these paintings is found in different databases (museum albums will from here on be included in the term "database"), but also worth checking how large differences could be found of the same object in the two versions, painted some decades apart. This can give an insight into the colour memory [11] of the painter and give us some hint how important he thought the colour of a given object was. This can be especially important for human skin tones, as we are often very critical as regards the reproduction of skin tones, as well as the blue of the robe of the Madonna (as this blue had heraldic information too).

Seven artefacts shown on the Internet of the subject have been analysed; four of them were reproductions of the Louvre version [12]-[14], and two of the National Gallery version [12], [14], [15]. Further, two printed versions of the Louvre and one of the National Gallery versions were included in our investigation.

Figure 2 shows the example of the Louvre version, with three areas of skin tones (the forehead of the Madonna and of the angle and the leg of St. John) marked with a white circle. As second hue, the blue of the robe of the Madonna was selected, a portion on her shoulder in the Louvre version and on the breast on the National Gallery version. Also, these areas are shown in the picture by small circles. These are areas that could also be easily identified on the London version of the picture. Further versions were selected from museum albums [16]-[18] where some parts of the pictures were enlarged and could be measured with higher accuracy.

Table 1 shows the L^*, a^*, b^* values measured for the three selected skin tones and the portion of the robe, measured on the artefacts from different databases of the Louvre version of the picture.

Similar measurements were made on artefacts of the London version of the painting. For this we show in Table 2 data, from different databases, for the forehead of the Madonna, as this is a critical skin tone. As can be seen, we got only in one case a pale yellowish colour ($h_{ab}^* \approx 60°$); in two other cases reddish hues were obtained ($h_{ab}^* \approx 0°$).

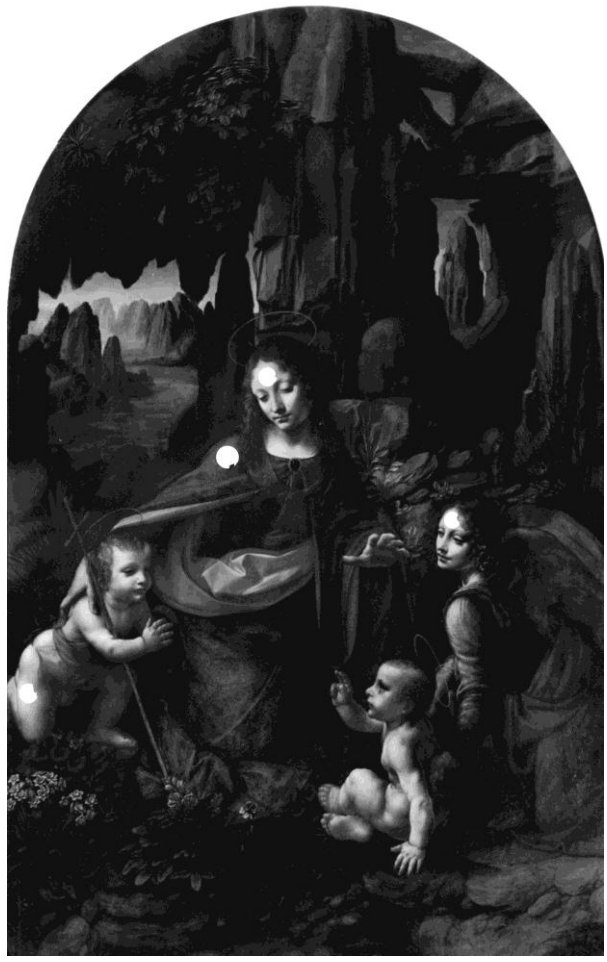

Figure 2
Black and white reproduction of the Virgin of the Rocks picture, showing the four parts were colour measurement was made.

Table 1
Average skin tones, colour of the robe of Maria and their standard deviations (in brackets) for four parts of the Madonna of the Rocks (Louvre) painting using the Photoshop eye-drop tool, based on seven Internet reproductions

Part of the picture	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
Forehead of the Madonna	81 (±13)	4 (±2)	37 (±2)	84	37
Forehead of the angle	78 (±13)	13 (±3)	39 (±9)	72	41
Leg of St.John	71 (±2)	19 (±4)	46 (±5)	68	50
Robe of Mary	42 (±10)	-12 (±2)	21 (±7)	300	24

Table 2

Skin tones of the forehead of the Madonna, measured with the Photoshop eye-drop tool on artefacts from different databases reproducing the Virgin on the Rocks, National Gallery London version

L^*	a^*	b^*	h_{ab^*}	C_{ab}^*
96	-3	19	279	19
88	5	9	61	10
99	-5	22	283	23

Table 3

Average skin tones, colour of the robe of Maria and their standard deviations (in brackets) for four parts of the Madonna of the Rocks (Louvre) painting: (A), and of the Virgin of the Rocks (Nat. Gal., London) painting: (B); using the i1 instrument, based on seven Internet reproductions

Part of the picture	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
A.) Forehead of the Madonna	82 (±11)	12 (±4)	39 (±6)	73	41
Forehead of the angle	80 (±11)	21(±6)	45 (±11)	75	50
Leg of St.John	67 (±11)	18 (±5)	36 (±10)	63	40
Robe of Mary	48 (±7)	0 (±3)	2 (±4)	-	2
B.) Forehead of the Madonna	88 (±13)	7 (±6)	23 (+14)	73	24
Forehead of the angle	90 (±4)	6 (±5)	25 (±17)	77	26
Leg of St.John	87 (±5)	9 (±4)	27(±10)	72	28
Robe of Mary	55(±2)	3 (±4)	-17 (±5)	280	17

Table 4

Average skin tones, colour of the robe of for four parts of the Madonna of the Rocks (Louvre) painting: (A), and of the Virgin of the Rocks (Nat. Gal., London) painting: (B); using the i1 instrument, based on a printed book image

Part of the picture	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
A.) Forehead of the Madonna	77	3	35	85	35
Forehead of the angle	72	10	40	76	41
Leg of St.John	72	12	34	71	36
B.) Forehead of the Madonna	74	13	22	59	26
Robe of Mary	45	-1	-9	264	9

Similar investigations were made using the famous picture Mona Lisa, taken from [13] and [14], and the Lady with an Ermine, taken from [14] and [16]. In these artefacts, the colour of the forehead was investigated. We show the average results obtained when the measurements were taken on the monitor screen by Photoshop and by i1, as well as from albums, using the i1 instrument.

Table 5
Average skin tones and their standard deviations measured on the forehead of the Mona Lisa and the Lady with an Ermine

Picture and measurement	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
A.) Mona Lisa, Photoshop	84 (±5)	5 (±5)	53 (±11)	85	53
Mona Lisa, monitor, i1	87 (±3)	9 (±2)	49 (±11)	80	50
Mona Lisa, album, i1	63 (±3)	9 (±2)	30 (±2)	73	31
B.) Lady w. Er., Photoshop	80	14	38	70	40
Lady w. Er., monitor, i1	78	20	41	64	46
Lady w. Er., album, i1	73	7	24	74	25

2.1 Paintings by Vincent van Gogh

As another example, we selected another masterpiece, Vincent van Gogh's Bedroom, available as three original paintings now in the Art Institute of Chicago, the van Gogh Museum, Amsterdam and the Musée d'Orsay. The big difference compared to Leonardo's paintings is that, while the originals of the two Madonna/Virgin on the Rocks paintings are very similar and radiate the same feeling, the three van Gogh paintings show exactly the same room but painted in very different moods; thus the differences in coloration must be reproduced exactly in order to be able to evaluate the differences. Three Internet databases [19]-[21] (in one of them, several versions of the painting were found) and two books [22], [23] and an art poster [24] have been included in this search.

Again, both the Photoshop eye-drop technique and the i1 instrument were used for the picture displayed on the monitor, and the i1 was used for measuring colours in the printed versions. Figure 3 shows a black-and-white reproduction of one of the pictures, in which the five areas where measurements were taken are shown by white circles. The graphical part of the three originals is very similar and one has to look at the details of the paintings carefully to see the differences; on the other hand the coloration of the three originals is strikingly different.

Number 1 is a part of the bluish green window, 2 represents a part of the blue wall, 3 is a part of the yellow pillow, 4 is a reddish eiderdown, 5 is a brown wood colour. Table 6 shows in the example of the van Gogh Museum Amsterdam version the colorimetric values measured on three artefacts downloaded from the Internet, measured with the i1 instrument.

Figure 3
Vincent van Gogh's The bedroom painting, The Art Institute of Chicago version

Table 6
Colorimetric data for D50 illumination and 2°observation of artefacts downloaded from three Internet databases of Vincent van Gogh's Bedroom, van Gogh Museum Amsterdam version, measured with i1 instrument

1.) window	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
Database 1	59	-12	28	293	30
Database 2	66	-5	41	277	41
Database 3	77	-13	47	285	49
Average (AVE)	*67*	*-10*	*39*	284	40
Standard deviation (STD)	*9*	*4*	*10*		
2.) wall					
Database 1	58	-14	-6	203	15
Database 2	79	-7	-22	252	23
Database 3	86	-6	-12	243	13
Average (AVE)	*74*	*-9*	*-13*	235	16
Standard deviation (STD)	*14*	*5*	*8*		
3.) pillow					
Database 1	87	1	53	89	53
Database 2	87	11	52	78	53
Database 3	85	-1	51	271	51
Average (AVE)	*86*	*4*	*52*	86	52
Standard deviation (STD)	*1*	*7*	*1*		

4.) eiderdown					
Database 1	44	47	23	26	52
Database 2	49	55	31	29	63
Database 3	39	37	16	23	40
Average (AVE)	*44*	*46*	*23*	27	51
Standard deviation (STD)	*5*	*9*	*7*		
5.) bed, wood					
Database 1	70	42	54	52	68
Database 2	64	44	50	49	67
Database 3	77	20	62	72	65
Average (AVE)	*70*	*35*	*55*	58	65
Standard deviation (STD)	*7*	*13*	*6*		

As a next step, the results via the three measurement techniques (Monitor picture with Photoshop and i1, printed copy with i1) were compared. All three Internet versions and a book copy were measured. The average measurement results are seen for the Amsterdam version of "The bedroom" in Table 7.

Table 7

Colorimetric for D50 illumination and 2°observation determined on artefacts of Vincent van Gogh's Bedroom, van Gogh Museum Amsterdam version

1.) window:	L^*	a^*	b^*	h_{ab}^*	C_{ab}^*
Internet picture, Photoshop eye-drop	68	-15	47	288	49
Internet picture, i1 instrument	67	-10	39	284	40
Printed copy, i1 instrument	81	-6	49	277	49
AVE	72	-10	45	283	46
STD	8	5	6		
2.) wall					
Internet picture, Photoshop eye-drop	71	-12	-11	223	16
Internet picture, i1 instrument	74	-9	-13	235	16
Printed copy, i1 instrument	72	-11	-10	222	15
AVE	73	-11	-11	225	16
STD	2	2	2		
3.) pillow					
Internet picture, Photoshop eye-drop	83	2	64	88	64
Internet picture, i1 instrument	86	4	52	86	52
Printed copy, i1 instrument	65	9	40	77	41
AVE	78	5	52	85	52
STD	12	4	12		

4.) eiderdown					
Internet picture, Photoshop eye-drop	37	52	47	42	70
Internet picture, i1 instrument	44	46	23	27	51
Printed copy, i1 instrument	55	23	33	55	40
AVE	45	40	35	41	53
STD	9	15	12		
5.) bed, wood					
Internet picture, Photoshop eye-drop	69	34	70	64	78
Internet picture, i1 instrument	70	35	55	58	65
Printed copy, i1 instrument	70	12	54	77	55
AVE	70	27	60	66	66
STD	1	13	9		

Similar measurements were made on three Internet versions of the image from the Artistic Institute, Chicago, and on two Internet copies of the d'Orsay version of the "The Bedroom" picture.

3 Discussion

As can be seen from the different tables, the colours of the selected objects show considerable scatter. Investigating Leonardo's paintings, if a more detailed analysis is made, some quite unexpected discrepancies can be found: e.g. one of the databases contained four artefacts of the Madonna of the Rocks. In three of them the L^* value (lightness) of the complexion of the Madonna was within 1.5%, but the fourth one differed by almost 30%. Similar differences were found also for the lightness of other parts of the picture, but the hue angles of the objects were quite close to each other.

The Mona Lisa complexion lightness was quite similar in the three Internet databases, but the book reproduction differed considerably, however. On the other hand the hue angle differences were within acceptable tolerances.

Analysing the data of the van Gogh paintings, one must state that the artefacts of the same original differ considerably and not systematically in the different databases. This can be seen for example on the data as reproduced in Table 6: Comparing the CIE lightness data of the three datasets, we see e.g. that while for the pillow, the first two show the same value ($L^* = 87$), and the third one is only slightly lower ($L^* = 85$), for the bed colour the CIE lightness as shown in the third database is 10% higher than that from database number 1. This brings already an imbalance in the coloration of the artefact. Also, the hue angles show considerable differences, especially for the bed colour: In one case we see an almost orange colour, while in the other case it is a pale yellowish hue.

Similar differences can be found also for the blue wall colour, although in that case the lightness of the wall is much higher in the artefact of database 2, compared to database 1, which is just the opposite as for the bed colour. In summary, we must state that the three colorations used in the three databases deliver quite different messages to the viewer. And this is not a simple coding error of the originally taken analogue data, as in that case we would see systematic distortions, less obvious to the human eye.

4 Consequences

We agree with Borbely [27] that to reproduce colored images correctly, colour management has to be used and even in that case with modern LCD displays problems with crosstalk in the display might produce further problems. Thus when taking the digital images, all the background information should be captured; and similarly, the reproducing projector must to be calibrated. The remaining small errors produced by differences between the monitor and the projector can usually be neglected.

4.1 Consequences for the Art Teacher

As shown in the discussion section one observes quite often in different artefacts of one and the same original image that the colours of different objects move in different directions of colour space.

As regards the Madonna/Virgin on the Rocks, it is interesting that if one compares not two extreme artefacts, one finds that Leonardo used decades later practically the same colours: looking at Tables 3 and 4, if one considers the scatter between the different artefacts, it is striking how similar the lightness and the hue angles of the forehead of the Madonna in the two paintings are. (As mentioned, for the Louvre version in one and the same database two artefacts were found that showed strikingly different coloration; such "bad" reproductions should not be considered.) It is interesting that the chroma (the vividness of the colour) is different in the artefacts of the two paintings (see C_{ab}* for the forehead both of the Madonna and of the angle, but also of the leg of St.John, i.e. "skin tones"): on the London version these flesh tone colours are less vivid, but the lightness is practically the same. From this, one can conclude that these artefacts reproduce correctly the three dimensions of the flesh tones (hue, lightness and chroma). Leonardo seems to have used similar colour attributes also for his other (analysed) paintings, as is shown in Table 5 for the skin tones of the Mona Lisa and the Lady with the Ermine.

The picture is not so clear in the case of the van Gogh paintings. There are on the one side large differences for one and the same object of the same painting

if the artefact is take from different databases, but because the human eye is more sensitive to them, it is more critical if the chromaticity of two objects changes in different directions in colour space. Thus, for example, as seen from Table 6, comparing Databases 1, 2 and 3, the window and wall lightness increase from 1 to 2 to 3, but the pillow lightness stays practically constant, and that of the eiderdown decreases. But what is even more critical is that, at the same time, the hue of the window changes from bluish towards greenish (decreasing hue angle), but for the wall colour the hue angle increases, from greenish towards bluish; thus, the hue difference between wall and window hue decreases. This can produce an imbalance in the picture's colour impression. Similar distortions can be observed when the colours of the van Gogh Museum artefacts are compared.

Such problems make it difficult for the art teacher to select the best reproduction setting for his equipment. All the fine tuning possibilities of present day image manipulating software (e.g. setting chromatic adaptation, gamma correction based on surround brightness, etc.) [6], based on CIECAM02 colour appearance model [28], [29], are in vain if the image providers do not supply the necessary metadata with the images.

4.2 Consequences for Technicians of Museums

Modern imaging technologies provide the means to tag the images with metadata describing all the information needed to reproduce the image in a colour correct form: information on the illumination used (not only correlated colour temperature, but spectral distribution, or at least colour rendering indices), spectral responsivity of the image-taking camera, its gamma characteristics, etc. These are all known when the picture is taken, and if it could be communicated together with the image, it would be possible to reproduce the image colour correctly, just as is done in many technical colour communication applications in the textile or paper industry.

Summary and Conclusion

Based on the examples discussed in this paper, we must conclude that the digital artefacts of famous paintings now available on the Internet are – at least partly – poor reproductions of the original. Techniques now available to set the colorimetric characteristics of the different imaging devices (monitors, printers, projectors) provide better agreement between these devices as to what one can expect by downloading artefacts from different databases. This is certainly a bad message for the art teacher who would like to use these images in his classes.

The first and most important message to the art teacher is not to rely on one single reproduction, downloaded from one database, but to check for more copies of the same painting, and to compare their colours before selecting one

to be shown in the classroom. On the other side, we should mention that on the receiving side, i.e. reproducing the pictures in the class-room, for the time being not much can be done to increase colour fidelity.

To the providers of the artefacts one should direct the plea to provide with the reproduction also some information as to how the reproduction was made: illuminant used to take the picture, encoding, eventual transformations (e.g. lightness scale distortions), etc. This could help in the future to set the necessary transformations to get on the screen the colour impression one would have by looking at the original in the museum.

References

[1] C. F. Andersen, J. Y. Hardeberg, "Colorimetric Characterization of Digital Cameras Preserving Hue Planes", *Proc. 13 Color Imaging Conf.*, 2005, pp. 141-146

[2] L. W. MacDonald, W. Ji, "Colour Characterization of a High-Resolution Digital Camera", *Proc. First Internat. Conf. on Colour in Graphics. Imaging and Vision*, 2002, pp. 433-437

[3] R. S. Berns, "Rejuvenating the Appearance of Cultural Heritage Using Color and Imaging Science Techniques", *Proc. AIC Colour '05*, 2005, pp. 369-374

[4] M. Mohammadi, R. S. Berns, "Diagnosing and Correcting Systematic Errors in Spectral-based Digital Imaging", *Proc. 13 Color Imaging Conf*, 2005, pp. 25-30

[5] IEC (1999) IEC 61966–2–1: Multimedia Systems and Equipment – Colour Measurement and Management – Part 2–1: Colour Management – Default RGB Colour Space – sRGB, IEC, Switzerland, 1999

[6] J. Morovic, J. Lammens J, *Colour Management in Colorimetry, in Understanding the CIE System*, ed. J Schanda,.Wiley Interscience, New Jersey, 2007, pp. 159-206

[7] E. J. Giorgianni, T. E. Madden, K. E. Spaulding, *Color Managamanet for Digital Imaging Systems, in Digital Color Imaging*, ed.: G Sharma, CRC Press, Boca Raton, London, New York, Washington D.C., 2003, pp. 239-268

[8] CIE 15:2004 Colorimetry, CIE Central Bureau, Vienna, Austria, 2004

[9] J. Schanda, *CIE Colorimetry in Colorimetry, Understanding the CIE System*, ed. J Schanda, Wiley Interscience, New Jersey, 2007, pp. 25-78

[10] D. C. Rich, D. L. Alston, L. H. Allen, "Psychophysical Verification of the Accuracy of Color and Color-Difference Simulations of Surface Samples on a CRT display", *Color Res. & Appl.* Vol. **17**, No. 1. 1992, pp. 45-56

[11] P. Bodrogi, T. Tarczali, „Investigation of Colour Memory", *Colour Image Science: Exploiting Digital Media*, ed. LW MacDonald and MR Luo, John Wiley & Sons Limited, Chichester, 2002, pp. 23-47

[12] Leonardo: Sziklás Madonna,: http://www.sk-szeged.hu/virtualis-kiallitasok/virtualis-kiallitasok/30/134-virtualis-kiallitasok-kepzmveszet.html

[13] Atlas Database of the Louvre: http://cartelen.louvre.fr/cartelen/visite?srv=crt_frm_rs&langue=fr&initCritere=true

[14] http://en.wikipedia.org/wiki/Leonardo

[15] http://www.nationalgallery.co.uk/

[16] M. Pomilio, *L'opera completa di Leonardo pittore, Rizzoli Editiore,* Milano, 1967

[17] K.H. Clasen, *A Louvre képtára*, Képzőművészeti Alap Kiadóvállalat, Budapest, 1964

[18] Z. Zsámboki, *National Galery, London*.,Corvina, Budapest, 1988

[19] http://www.artic.edu/artaccess/AA_Impressionist/

[20] http://www.3dsrc.com/vangogh/vincent%20vangogh%20-%20La%20chambre%20de%20Van%20Gogh%20a%20Arles.php

[21] http://www.vggallery.com/painting/

[22] R. Hughes, *van Gogh*, Kopakt, Belser Verl. Stuttgart, 2003

[23] R. Metzger, I.F. Walther, *Vincent van Gogh*, Taschen/Vince Kiadó Budapest, 2004

[24] *Art & Image Bestseller Calendar 2006*, Neues Verlag, Kempen, 2006

[25] J. Schanda, C. Sik Lanyi, "Colour Correct Digital Museum on the Internet, Virtual Reality," *Proc. HCII 2007, Lecture Notes in Computer Science, LNCS 4563*, 2007, pp. 708-717

[26] C. Sik Lanyi, A. Sik, G. Sik, J. Schanda , "Colour Fidelity in Reproductions and Popular Images*", Proc. AIC 2008 Colour – Effects & Affects*, 2008, pp. 211-212

[27] Á. Borbély, "Accurate Colour Reproduction in Prepress*", Acta Polytechnica Hungarica*, Vol. **5**, No. 3, 2008, pp. 5-10

[28] CIE (2004) *A Colour Appearance Model for Colour Management Systems: CIECAM02*, CIE Publ. 159:2004, 2004

[29] M. R. Luo, C.L. Li, *CIE Colour Appearance Models and Associated Color Spaces*, in Understanding the CIE System, ed. J Schanda,.Wiley Interscience, 2007, pp. 261-294