

Comparison of color gamut volumes among ink-jet prints made on different types of paper

Keywords: papers suitable for ink-jet, papers applied in offset printing technique, machine with pigment aqueous-based inks, machine with UV-curable inks, gamut volume, colorimetric spaces, color appearance model

Introduction

Ink-jet is a digital printing technology which is used for many types of task, i.e. brochures, catalogues, advertising, packaging and books. Thanks to the newest solutions in machine and ink production, the quality of printing has improved. Furthermore, ink-jet as a digital technology can be used for carrying out very short runlengths. This constitutes a very important issue nowadays since the digital printing market was estimated to grow by 71% from 2008 to 2013 year. [1, 2]

There are many kinds of papers suitable for ink-jet, yet they are rather expensive. This is the reason why users of digital machines search for cheaper equivalents, i.e. offset papers. Unfortunately, such papers can give bad printing quality. Before using them, a considerable number tests should be carried out in order to check what types of offset paper are useful in ink-jet technique.

Results

Papers suitable for ink-jet and papers usually applied in offset printing technique were printed using two types of ink-jet machine – with pigment aqueous-based inks and UV-curable inks. Before the production, these two machines were calibrated: transformation related to the linearization and the ink limit was carried out (Color Management disabled).

Papers were printed by ANSI IT8/7.3 color chart with 928 control patches. The spectral reflectance of all patches was measured using SpectroScan (Gretag Macbeth) and colorimetric properties: illuminant D50 and standard color observer, angle 2°.

The results were presented in two colorimetric spaces: CIEXYZ, CIELAB and color appearance model space: CIECAM02.

In order to estimate gamut volume, the MatLab program was used. The only thing that was taken into consideration was CMY gamut, when K=0. First Delaunay's tetrahedralization of 250 points set in cube $\langle 0,1 \rangle^3$ was performed. After tetrahedralization, there were 863 tetrahedrons set available. In the next stage it was checked if cube tetrahedralization transferred to CIEXYZ, CIELAB and

CIECAM02 was still tetrahedral division. It means that it was checked whether an intersection of tetrahedrons was a triangle, wall, segment, vertex or an empty set. This allowed to find out whether there were any errors in measurement or during calibration. [3]

Additionally, the volume of color gamut for all papers printed with two different ink-jet machines was estimated. The results are given in the Table 1.

Table 1. Volumes of color gamut in CIEXYZ, CIELAB, CIECAM02

Type of ink and paper	Gamut volume		
	CIEXYZ	CIELAB	CIECAM02
1 UV-Curable paper suitable	60.516,00	401.191,46	405.723,62
2 UV-Curable uncoated 60 gsm	34.396,60	325.287,89	326.249,49
3 UV-Curable uncoated 450 gsm	58.233,89	377.719,54	390.421,60
4 UV-Curable uncoated bulky cream 70 gsm	34.767,43	241.031,01	254.493,44
5 UV-Curable uncoated bulky cream 350 gsm	56.186,03	326.353,39	339.512,51
6 UV-Curable coated 90 gsm	44.967,43	406.894,00	397.558,20
7 UV-Curable coated 250 gsm	60.895,26	451.440,83	445.246,08
8 UV-Curable coated bulky 90 gsm	43.252,61	396.330,38	387.831,72
9 UV-Curable coated bulky 250 gsm	59.652,20	448.470,47	441.602,65
1 Aqueous-based paper suitable	72.873,65	657.233,31	630.897,16
2 Aqueous-based uncoated 60 gsm	29.756,84	115.223,38	138.095,51
3 Aqueous-based uncoated 450 gsm	54.188,80	184.933,90	214.839,71
4 Aqueous-based uncoated bulky cream 70 gsm	33.830,65	139.867,87	159.203,20
5 Aqueous-based uncoated bulky cream 350 gsm	56.739,67	211.941,63	236.427,03
6 Aqueous-based coated 90 gsm	56.675,08	361.966,78	384.340,95
7 Aqueous-based coated 250 gsm	73.235,30	384.780,71	412.921,99
8 Aqueous-based coated bulky 90 gsm	53.446,19	303.881,20	328.455,08
9 Aqueous-based coated bulky 250 gsm	75.047,74	417.628,94	443.098,68

Present analysis compares values of gamut volumes

Papers suitable for digital printing have either the widest (the case of a device with aqueous-based inks) or one of the widest gamut volumes (as it happens in case of a device with UV-curable inks). However, especially in the case of printing with UV-curable inks, uncoated and coated papers in their maximum available grammage, have comparable volumes of gamut. As far as the CIELAB colorimetric space and CIECAM color appearance model space are concerned, they have even greatest values than papers suitable for ink-jet, whereas the uncoated and uncoated bulky papers in their minimum grammage possess the lowest gamut volume. This is probably due to the fact of thicker layer of papers with coating or papers without coating but in their maximum grammage. Such layers are more resistant to ink influence.

Papers suitable for machines with aqueous-based inks have the widest gamut volume in all color spaces. Only in CIEXYZ colorimetric space, two types of coated papers show comparable values. The other types of paper have much narrower

gamut volume, although those coated ones display bigger values than uncoated ones. All gamut volumes ordered from the lowest to the greatest are shown on Figure 1.

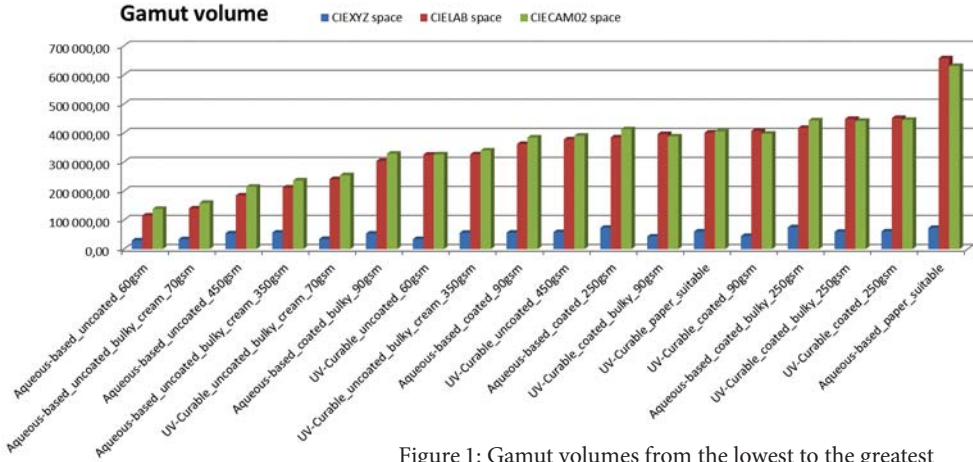
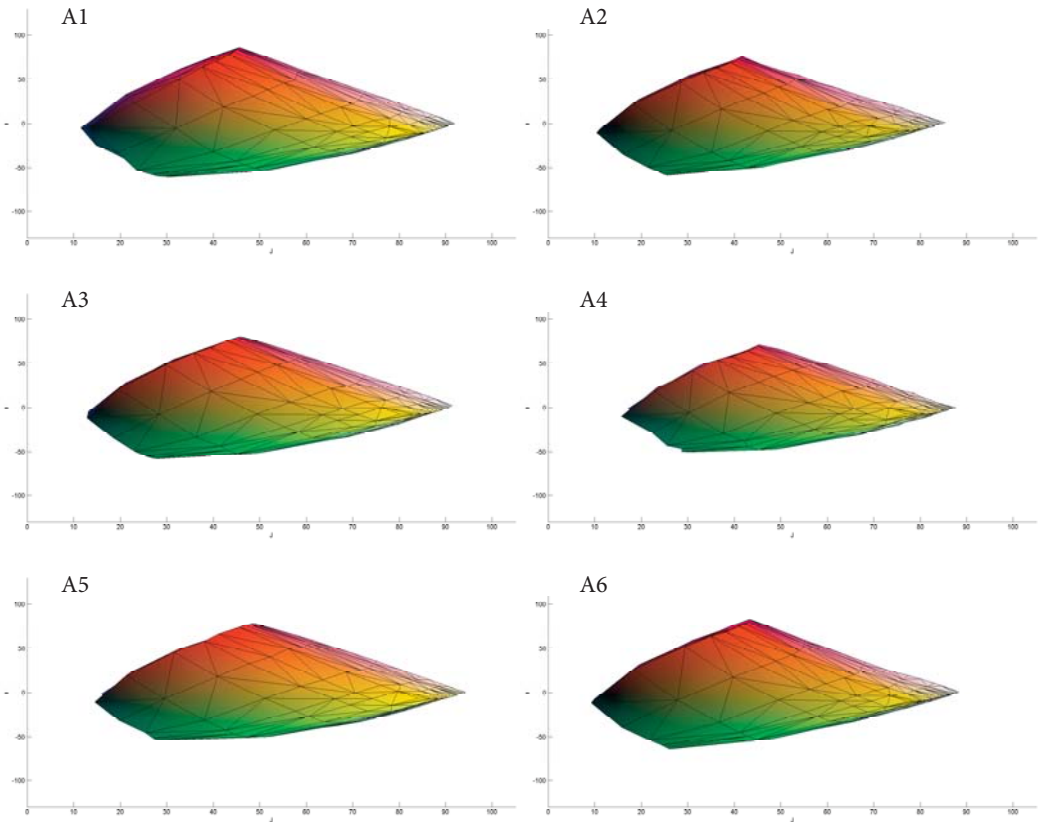


Figure 1: Gamut volumes from the lowest to the greatest

The visualization of color gamuts is illustrated on Figures 2–14.



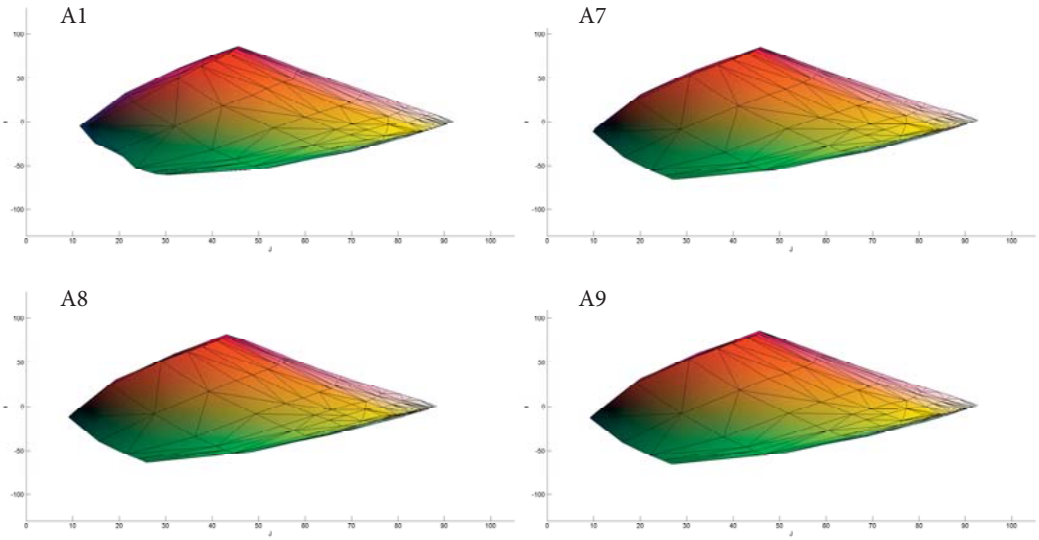
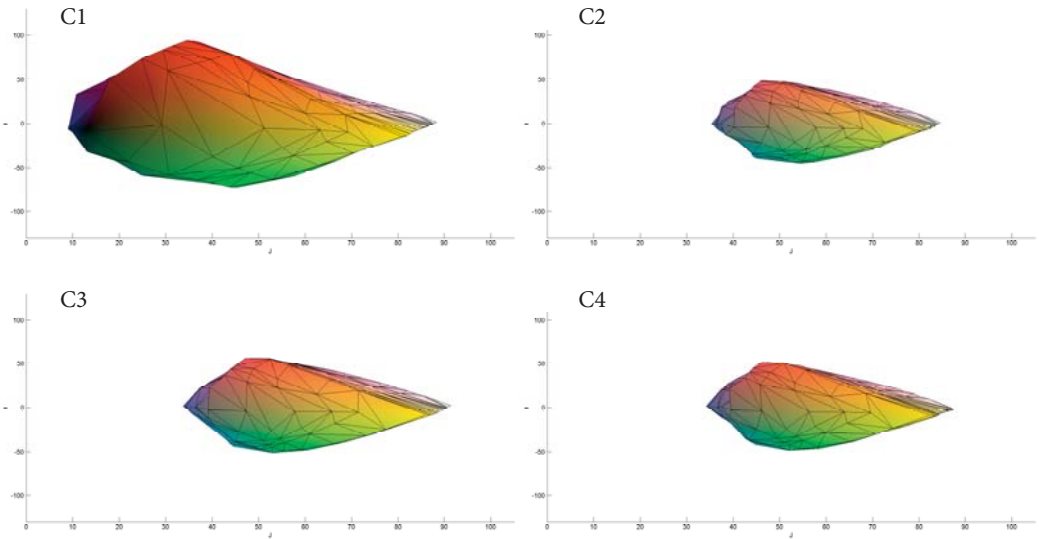


Fig. 2–3: Color gamut in CIECAM02 color appearance model – “A” means printing device with UV Curable ink, 1– paper dedicated to ink-jet, 2 – uncoated paper 60 gsm, 3 – uncoated paper 450 gsm, 4 – uncoated bulky cream paper 70 gsm, 5 – uncoated bulky cream paper 350 gsm, 6 – coated paper 90 gsm, 7 – coated paper 250 gsm, 8 – coated bulky paper 90 gsm, 9 – coated bulky paper 250 gsm

On Figures 2–3 the gamut CIECAM02 color appearance model space of papers printed with using UV Curable ink machines is represented. On the one hand, papers dedicated to ink-jet (A1) have wider volume gamut than uncoated papers in small grammage (A2, A4). On the other hand, volumes of their gamut are a little bit bigger than volumes of gamuts of offset coated papers (A7, A8, A9).



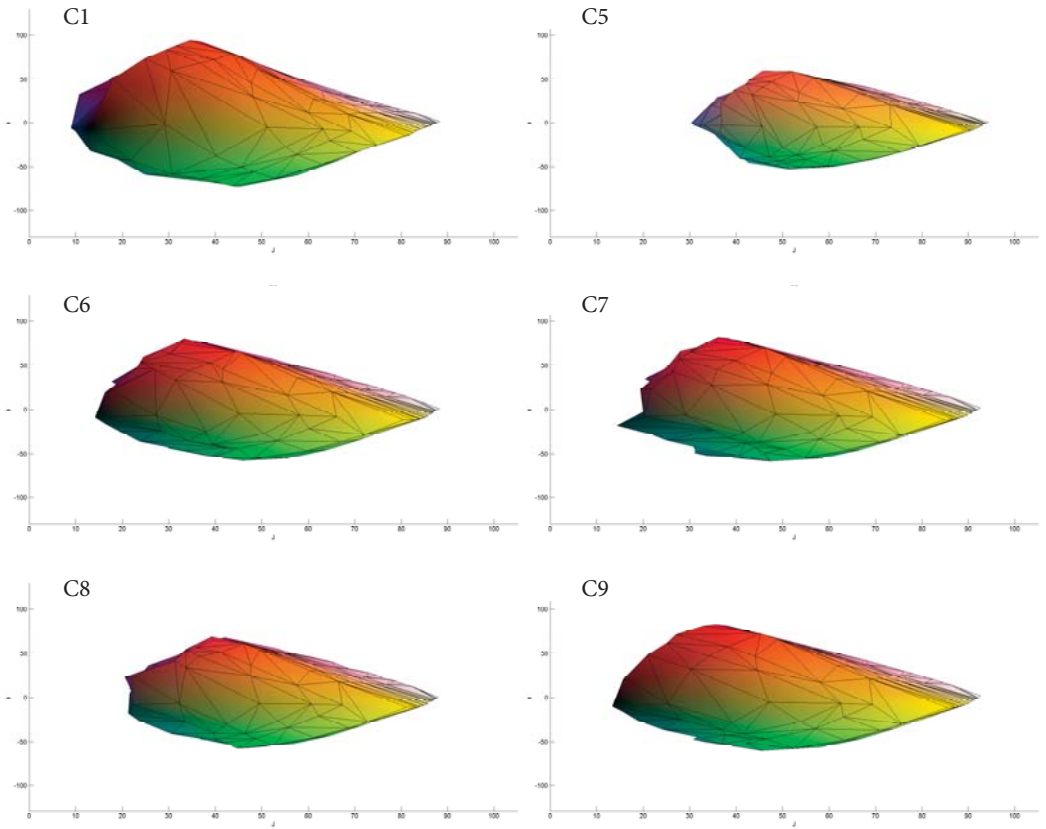
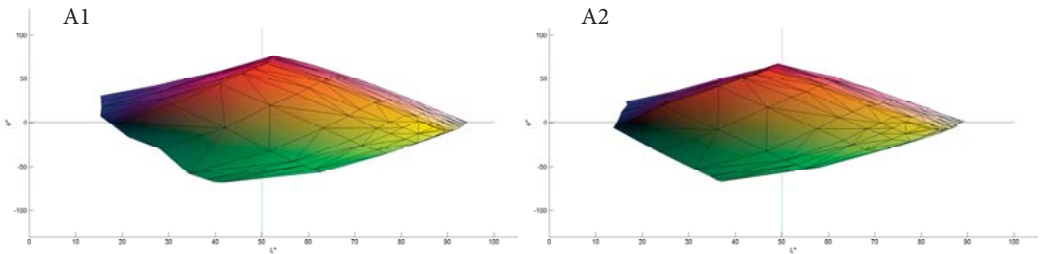


Fig. 4–5: Color gamut in CIECAM02 colorimetric space – “C” means printing device with aqueous-based ink, 1 – paper dedicated to ink-jet, 2 – uncoated paper 60 gsm, 3 – uncoated paper 450 gsm, 4 – uncoated bulky cream paper 70 gsm, 5 – uncoated bulky cream paper 350 gsm, 6 – coated paper 90 gsm, 7 – coated paper 250 gsm, 8 – coated bulky paper 90 gsm, 9 – coated bulky paper 250 gsm

On Figures 4–5 the CIECAM02 colorimetric spaces color gamuts of papers printed in aqueous-based ink machines are represented. This time, papers dedicated to ink-jet (C1) have much wider gamut than uncoated and coated papers, whereas the uncoated ones possess the lowest gamut volume.



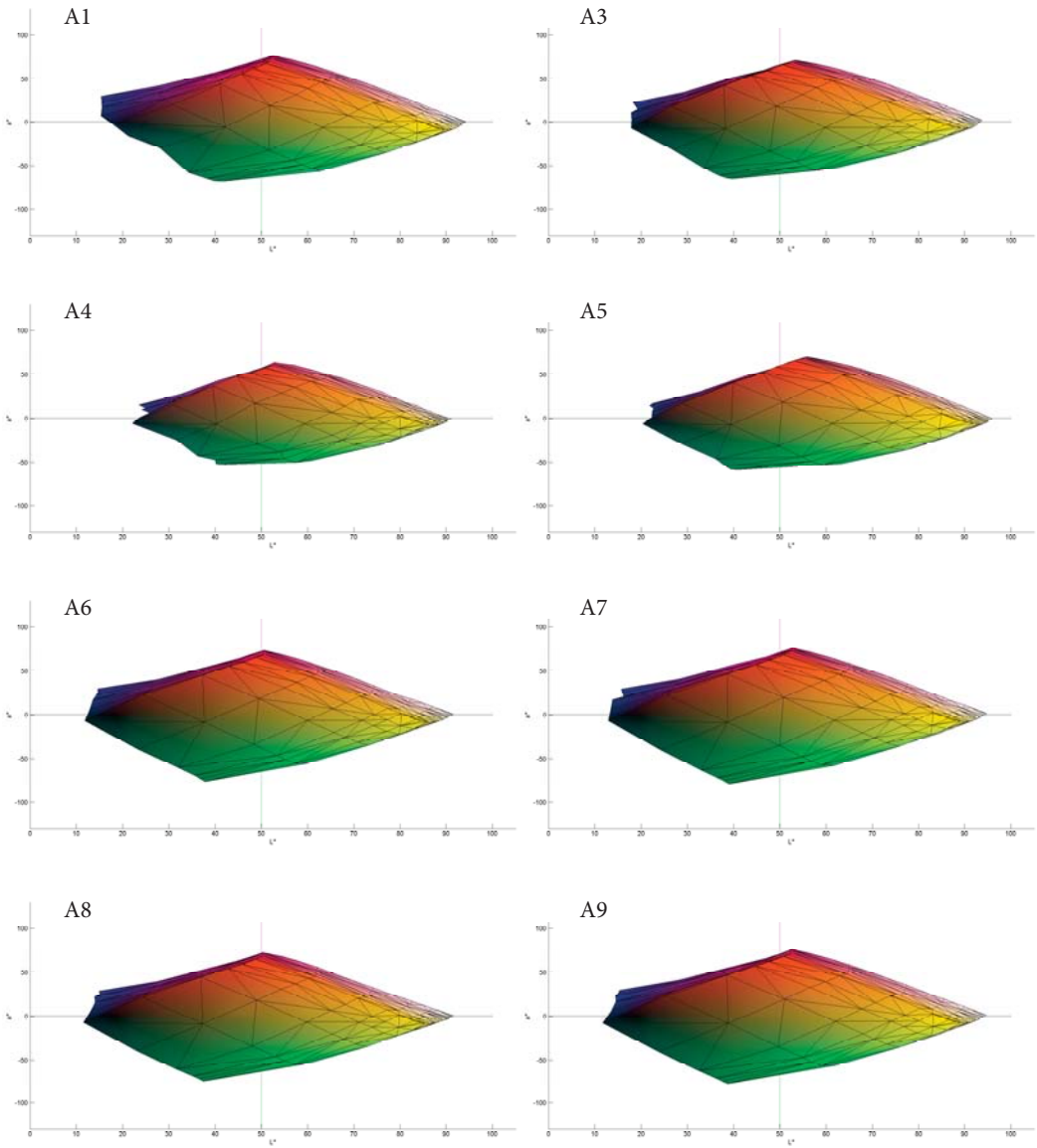
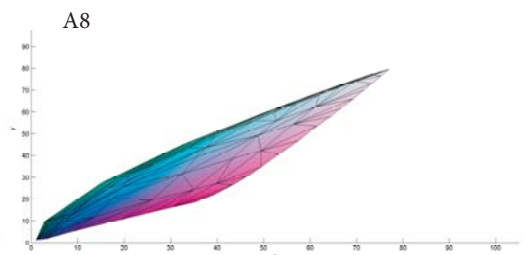
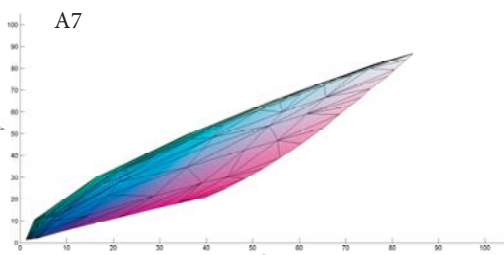
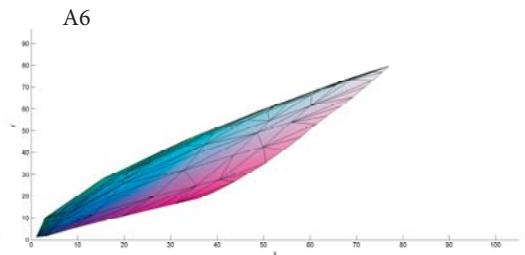
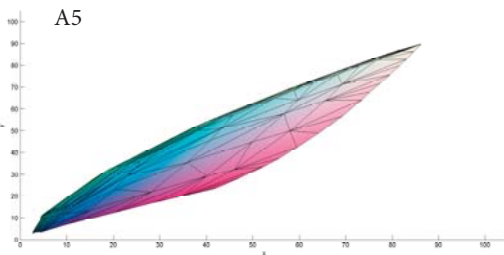
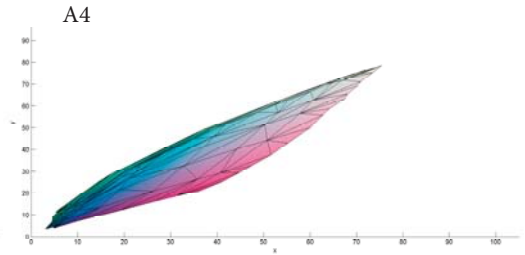
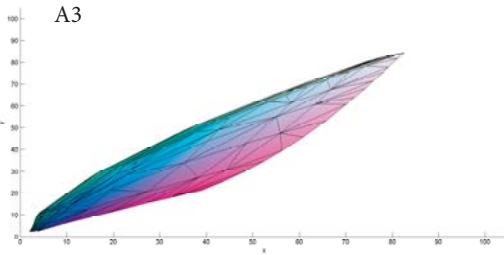
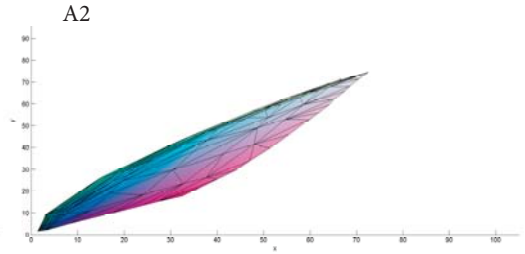
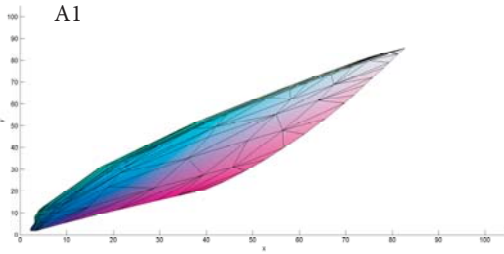


Fig. 6-7: Color gamut in CIELAB colorimetric space – “A” means printing device with UV Curable ink, 1 – paper dedicated to ink-jet, 2 – uncoated paper 60 gsm, 3 – uncoated paper 450 gsm, 4 – uncoated bulky cream paper 70 gsm, 5 – uncoated bulky cream paper 350 gsm, 6 – coated paper 90 gsm, 7 – coated paper 250 gsm, 8 – coated bulky paper 90 gsm, 9 – coated bulky paper 250 gsm

On Figures 6–7 the CIELAB colorimetric space of papers printed in UV Curable ink machines is represented. The types of color gamut volume are similar to those in CIECAM02: yet, although the papers suitable for ink-jet (A1) possess wider than uncoated papers in small grammage (A2, A4), their gamut volume is slightly lower than the one of offset coated papers (A7, A8, A9).



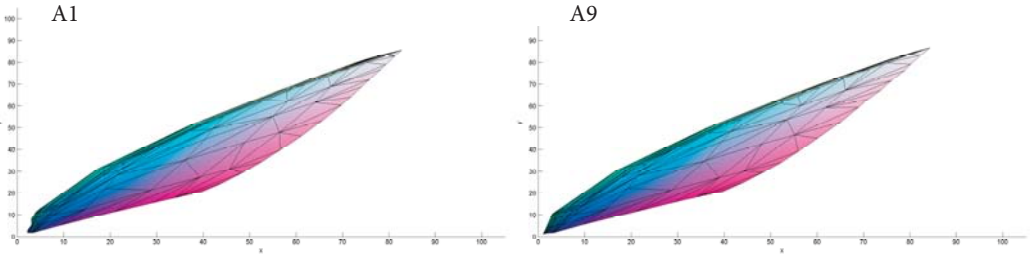
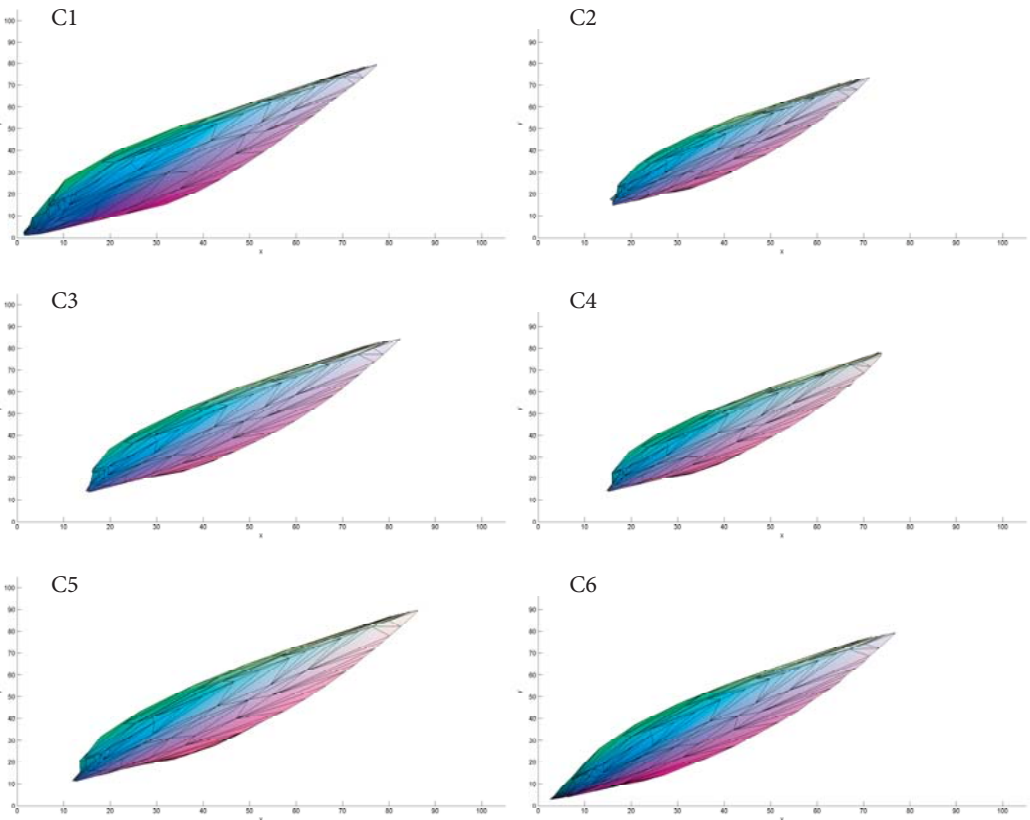


Fig. 8-9: Color gamut in CIEXYZ colorimetric space – “A” means printing device with UV Curable ink, 1 – paper dedicated to ink-jet, 2 – uncoated paper 60 gsm, 3 – uncoated paper 450 gsm, 4 – uncoated bulky cream paper 70 gsm, 5 – uncoated bulky cream paper 350 gsm, 6 – coated paper 90 gsm, 7 – coated paper 250 gsm, 8 – coated bulky paper 90 gsm, 9 – coated bulky paper 250 gsm

On Figures 8-9 the CIEXYZ colorimetric spaces color gamuts of papers printed in UV Curable ink machines are represented. Papers suitable for ink-jet (A1) have wider gamut volume than almost any paper used for offset. Only uncoated bulky cream paper in 350 gsm (A5) and coated bulky paper in 250 gsm (A9) have similar values to the one of papers suitable for digital machines.



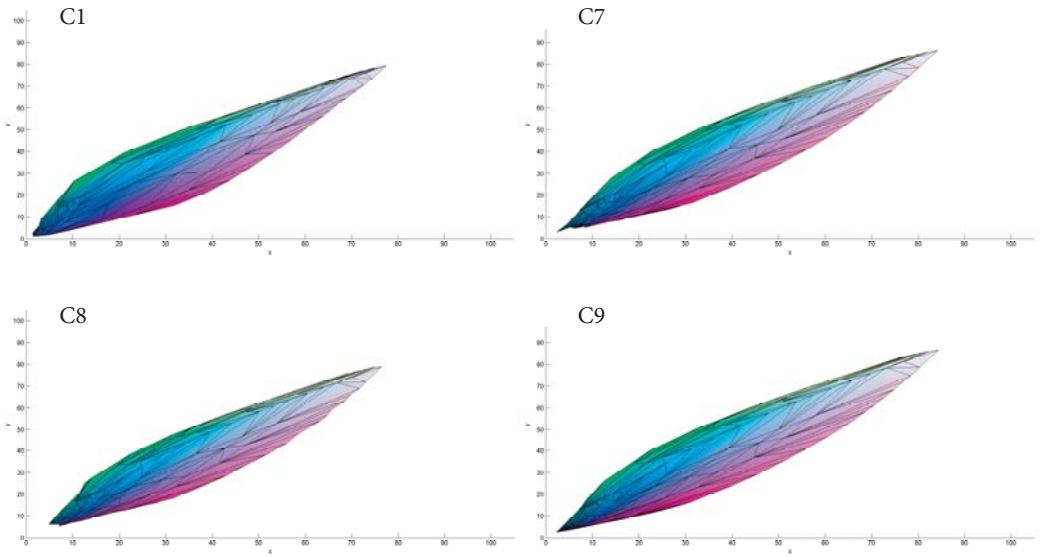


Fig. 10–11: Color gamut in CIEXYZ colorimetric space – “C” means printing device with aqueous-based ink, 1 – paper dedicated to ink-jet, 2 – uncoated paper 60 gsm, 3 – uncoated paper 450 gsm, 4 – uncoated bulky cream paper 70 gsm, 5 – uncoated bulky cream paper 350 gsm, 6 – coated paper 90 gsm, 7 – coated paper 250 gsm, 8 – coated bulky paper 90 gsm, 9 – coated bulky paper 250 gsm

On Figures 10–11 the CIEXYZ colorimetric spaces of papers printed with aqueous-based ink machines are represented. Papers suitable for ink-jet have one of the widest gamut volume, however coated paper in 250 gsm (C7) and coated bulky paper in 250 gsm (C9) have a little bit wider gamut. Two uncoated papers in small grammage – 60 and 70 gsm (C2, C4) have the narrowest one.

Conclusion

Although papers suitable for the digital ink-jet technique have one of the widest gamut volume, there are papers, usually used in offset printing machines, which display similar characteristics. It is most visible for prints made in UV machines. It proves that ink-jet printers can use not only “digital papers” but also coated papers in their maximum grammages. In case of aqueous-based ink machines have achieved only two types of coated papers in 250 gsm good results. Uncoated papers in their minimum grammage have the narrowest gamut volume.

The uncoated papers are quite unsuitable for the high-quality inkjet. What is more likely to be their unique employment is the formproof (layout-proof, ozalid process, etc.).

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Streszczenie

Porównanie objętości obszaru barw odtwarzalnych odbitek wykonanych cyfrową techniką natryskową na różnych rodzajach papieru

W artykule przedstawiono zagadnienie dotyczące możliwości stosowania papierów offsetowych (powlekanych i niepowlekanych) w drukowaniu cyfrowym natryskowym. W tym celu, po przeprowadzeniu odpowiedniej kalibracji maszyn, zadrukowano papiery dedykowane technice cyfrowej oraz te przeznaczone teoretycznie tylko do offsetu. W kolejnym etapie dokonano pomiarów spektrofotometrycznych, na podstawie których oszacowano objętość obszaru barw odtwarzalnych. W artykule zaprezentowano uzyskane wartości oraz sformułowano wnioski, z których wynika, że oprócz odbitek wykonanych na papierach dedykowanych technice cyfrowej, największą objętość obszaru barw odtwarzalnych mają odbitki wydrukowane na papierach offsetowych powlekanych o dużej gramaturze. Zależność ta występuje przede wszystkim dla wydruków wykonanych za pomocą maszyny wyposażonej w farby fotoutwardzalne. W przypadku odbitek pochodzących z urządzeń z farbami wodorozcieńczalnymi, zdecydowanie największą objętością obszaru barw odtwarzalnych charakteryzują się te wydrukowane na papierach dedykowanych technice cyfrowej. Najmniejszą objętością obszaru wykazały się odbitki wykonane na papierach niepowlekanych o małej gramaturze.