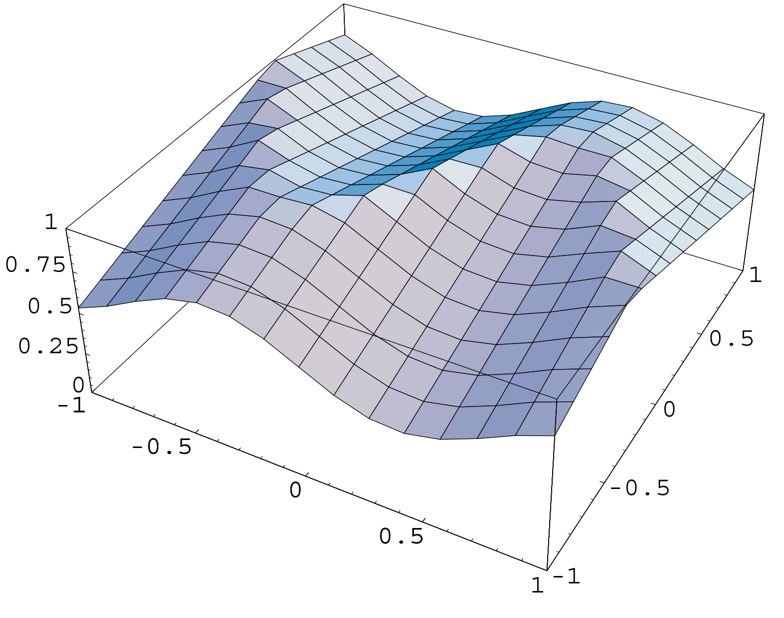
Pap • Žiljak • Vujić

Design of Digital Screening



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Design of Digital Screening
Klaudio Pap, Ivana Žiljak, Jana Žiljak-Vujić

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Contents:

Introduction

Progress of screening proposed by this book derives from the classic methodology of cluster dot order dithering, commonly known as halftoning based on the screen element (SE).

Screen element (SE) forms are mostly implemented in three shapes [1, pp. 141-143]: round dot, rhomb and line, since these can be produced by optomechanical procedures. These were the only shapes until a possibility of mathematical defining of screen cells [2]. Contemporary practice has been largely reduced to simulation of these three forms since their mathematical interpretations of growth function in screen cell have been published in the Postscript literature. This book offers a methodology of creating new screening models, and new models to prove research validity, as well as reasons for a necessity of opening up an area of individualized screening solutions. Proposed solutions are compatible with all printing technologies directly supported by the PostScript halftoning (binary printing technologies). It means that at the moment of applying this algorithm the multibit printing technologies should be adjusted to the binary operational mode (for each color separately). It applies to all technologies stated in this book.

A halftone screen element may be round, square, linear, linear in sinusoidal form, designed as a drop, as «coffee», as a tiny mesh, as a ring, as concentric rings, rotating forms, as a negative form of the above mentioned forms. Deformation of all the listed forms is mentioned here so that the round dot becomes an ellipse to the point of being a flat dash. In literature this concept is mentioned as a raster, screen element.

This book emphasizes the presence of various screen shapes. The authors on this issue, e.g. V. Ostromoukhow [3][4][5], propose the use of a blend technique to express a fixed predefined contour, e.g. in the Adobe Illustrator or FreeHand, for each grayscale. A respective contour should be screened for each grayscale. This book proposes a new manner oriented to creating areas of programmed screen forms in order to select shapes from this area by the stohastic selection, as well as to define angles from 0 to 90 degrees and screen rulings in the acceptable range of screen rulings of a printer. The creation of PostScript algorithms that depending on the seed generator of random numbers implement pseudo-random N of individual screen forms, angles and screen rulings, has resulted in a unique print by using one single number (SEED). This manner may be implemented in case of all contemporary PostScript RIP.

This book deals with the reproduction in a specific area that is more focused on a unique solution that cannot be repeated. A need for this type of application lies in the area of reproduction of graphics with a fixed number of prints, reproduction of postal stamps, securities and other documents printed digitally in a single copy; an integrated passport photograph, badge or pass. There has not been much research in this field due to a need for considerable funds in order to make an analogue real measuring base, e.g. postal stamps (philatelic interest) are still screened by classic screens [6][7] with no 'protective elements'. Screening simulation gives us a comprehensive insight into moire behaviour [8][6, pp. 43-61] and increase SE control [9][10][11][12][13].

A stohastic solution of print individualization is a border area of digital printing. Changes in PostScript commands enable a programming intervention during printing. Firstly, each printing sheet can have a new number, different image or text, prepared in a separate file. Secondly, individualization may be generated by an algorithm (commonly used in numeration), meaning that printed data are not in the memory, but created by logic defined in the PostScript program. This book contains a hypothesis that randomly selected parameters of lines and curves in the closed set of possible shifts or a randomly selected shape of a raster element for each pixel, present the highest degree of individualization. There are experiments with stohastic changes of the Bezier curve in vector graphics studied during the last few years and published partially [14].

This book offers an original approach to developing mathematical model of new screen cells by the ‘Mathematica’ program [15][16][17] since it has been used to create a visual graphic solution of an idea. In addition to providing a quantitative validity test, it has also produced a qualitative solution in visual-art terms.

Published articles of each author [18][19][20][21] present methodology for creating solutions that are not processed directly in the PostScript RIP. The attaching of predefined forms of each grayscale is carried out by PC as a rendering station for subsequent printing. A novelty in this book is the processing methodology in terms of the PostScript RIP printer. It implies that data on the input image move with the algorithm to RIP, and the SEED parameter that individualizes the image, generates a chain of random numbers from the RIP random number generator and not from the input PC. This is how the print becomes individualized not only by algorithms of new screen shapes, but also by a RIP printer with different PostScript random number generators in various printers. SEED parameter may be also regarded as the electronic signature of an image. If various SEED values are defined for each input color chanel, it is possible to achieve multiple combinations of protection against counterfeiters.

Each of existing published methodology - ‘art screening’ [3][4][5], ‘halftone no-screen procedures’ [21], ‘image-based screening’ [20] has a different aim. In this case the leading idea was a fact that up-to-date digital printing has developed and that it is being developed in the PostScript environment, so the methodology has developed with PostScript mechanisms ‘understood’ by all up-to-date printing devices.

The *Mathematica* program enables testing of a great number of forms that would have been only ideas with no practical application. Individualizing screen shapes means that on our disposal there is a parameter system of defining SE: on one hand it is a programmed numerical value that affects a SE shape (drawing), and on the other hand it is a possibility of partial selection of mathematical expressions.

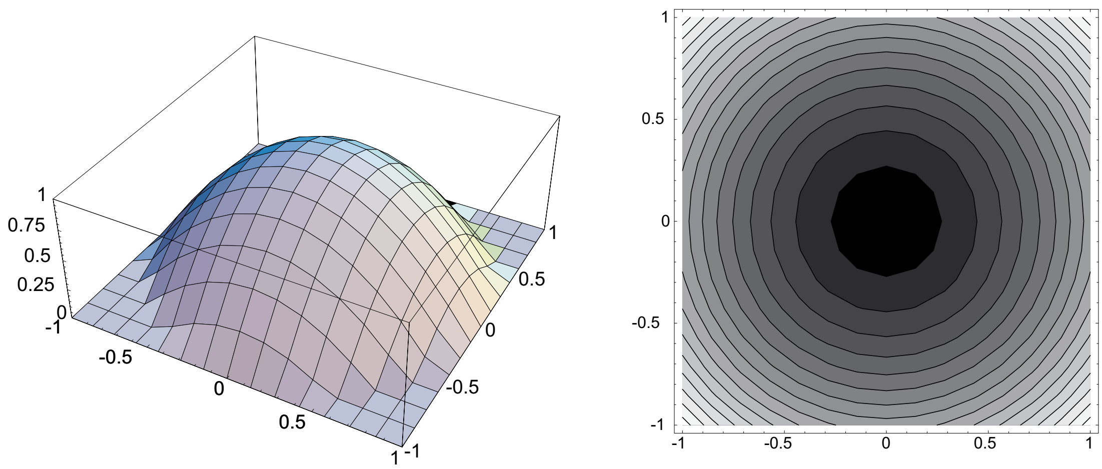
1. Matemathical model of a screen shape

The *Mathematica* program enables an illustration of validity of initial proposals. A decision on the SE selection has been brought following the screen cell animation. *Mathematica* enables testing of a great number of forms that would have been only ideas with no practical application. Marginal situations related to SE deformation require two-dimensional and three-dimensional display.

Figure 1 shows a model of a standard dot screen. Function *z=f(x,y)* defines a mathematical model of SE growth. *Plot3D* [22] and *ContourPlot* [23] are functions of the *Mathematica* program used for defining three-dimensional and two-dimensional display of growth of a respective SE mathematical model. There is a series of PostScript commands subsequently integrated into a final PostScript *set-screen* function [24].

The SE blackening area (SE) has been limited by a square cell. This is causing distortions of shapes already following the first contact with the barrier edge, and distortions continue until complete blackening. In the case of a rounded dot this event appears after the gray level of 78%. These tests favor 3D and 2D displays that are carried out easily by the *Mathematica* program.

The best manner for testing model efficiency is the application of a newly developed screen model in the grayscale range of 0% to 100%. This methodology has been illustrated by Figure 2 using an example of a standard dot screen. The SE has been applied to pixels starting with 5% gray level, followed by 10% gray level until 100% gray level in stages by 10%. A rough screen ruling of 4 lpi has been used in order to improve a review of SE development growth and the angle of 45 degrees that may be changed for reasons of experiment.



$$z= [x^2 + y^2]$$

3D : Plot3D [z,{x,-1,1},{y,-1,1},z={0,1}]

2D : ContourPlot[1-z,{x,-1,1},{y,-1,1},Contours=16]

PostScript: {dup mul exch dup mul add 1 exch sub}

Figure 1 *Model of dot screen*

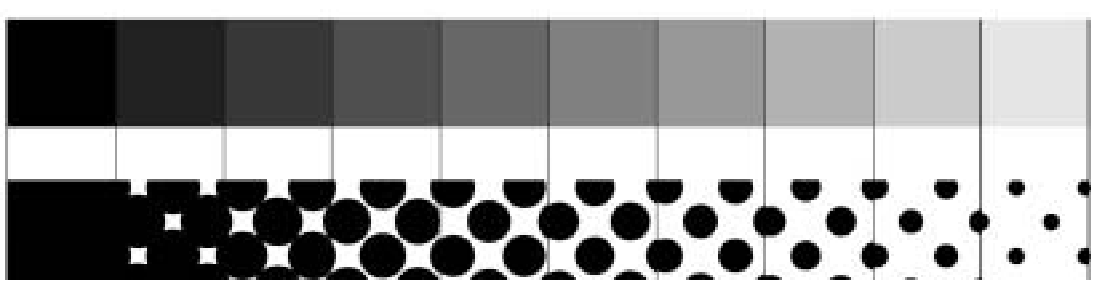
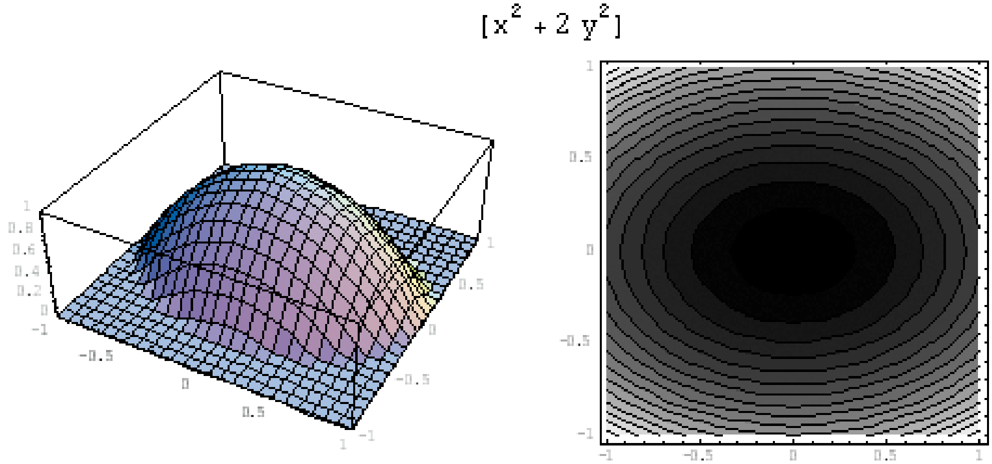


Figure 2 *Test picture elements with dot SE*

An elliptic shape (Figure 3) may be finalized from the rounded shape by unsymmetry of coefficients with variables *x* or *y*: A *z* function has been expressed by relation:



Slika 3 *Elliptic shape SE*

This shape must not be transformed directly into the PostScript function. It is necessary to check horizontal and vertical parameters in deformations to avoid a break in creating SE image in the *image* function. Research in this book has been expanded to detailed testing of internal SE deformation resulting in a series of parameters for each screen design with allowed screening areas.

The conventional model also includes a square form (Figure 4) and a straight line. Absolute values have been defined in order to use the definition area. A line as a screen element may be used for imitation of former manual screening methods. Various similar relations result in almost identical PostScript solutions, although in the mathematical sense, z functions are completely different. Therefore, two solutions resulting in different screen position (Figures 5 and 6). This position may be changed during screening, by means of the screen line angle. At present, both examples are considered equal in terms of screening. .

$\frac{1}{2}$ (Abs[x] + Abs[y])

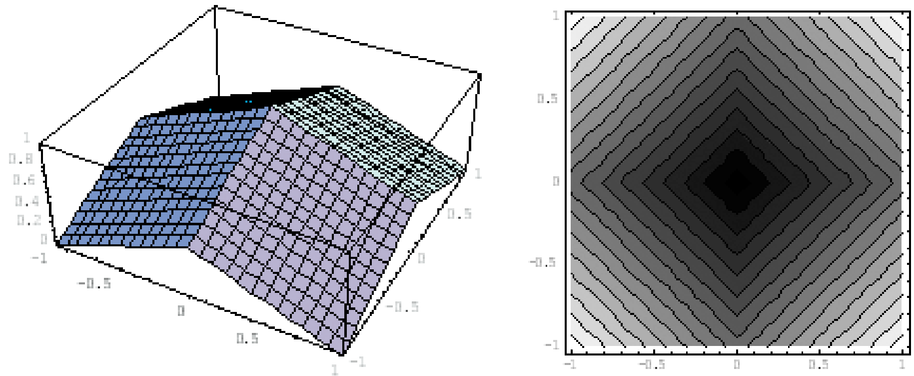


Figure 4 *Rhomb, square screening form*

$\frac{1}{2}$ Abs[x + y]

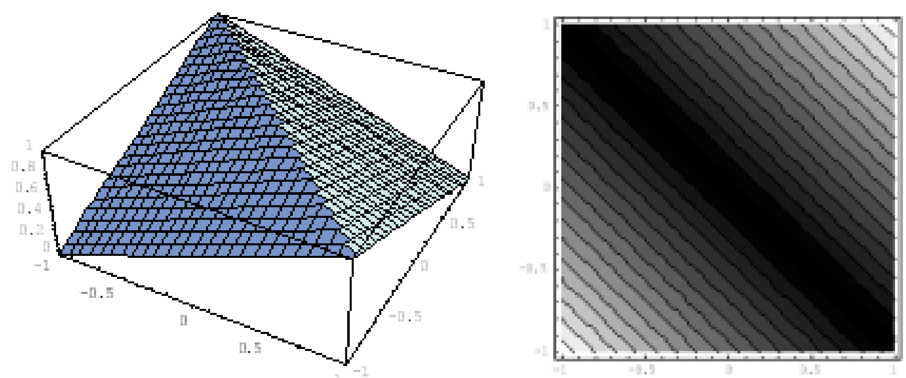


Figure 5 *Linear form with 'added' x and y variables*

$\frac{1}{2}$ Abs[x - y]

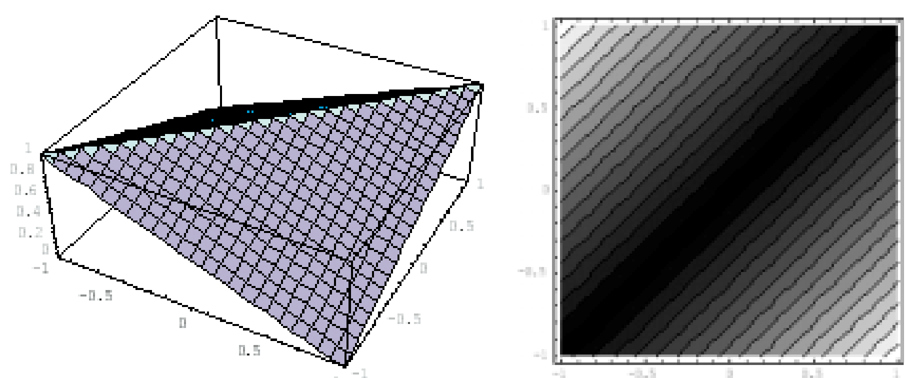


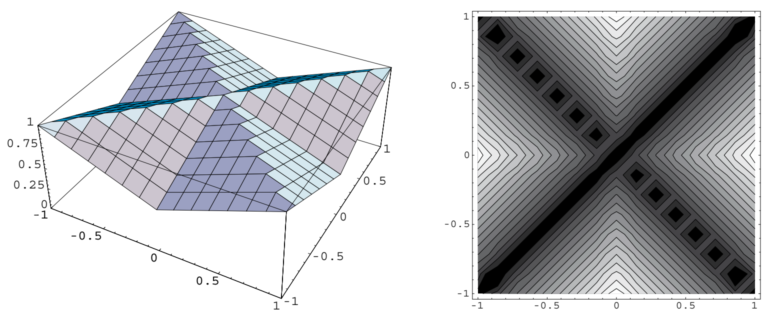
Figure 6 *Linear form with 'subtracted' x and y variables*

2. New screening models

A basic group of originally developed models with SE shapes includes app. 50 models. Figures no. 7, 8 and 9 show a group of 6 models.

Each model has a 3D and 2D display of SE growth, as well as respective mathematical and PostScript expressions described in the previous example of a standard dor SE. Models have been marked respectively, from r1 to r6 to facilitate program referral and subsequent search.

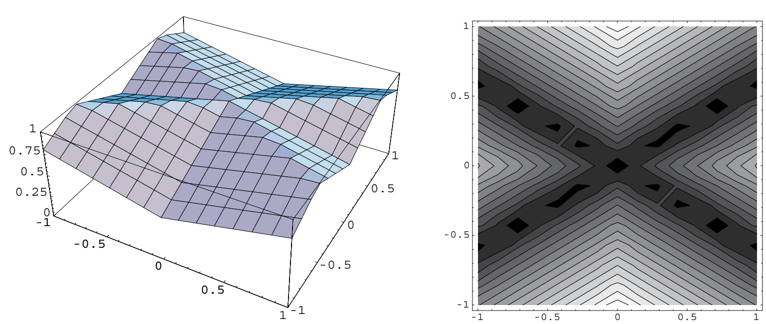
Model r1
cross



$$z = 1 - \frac{1}{2}\,\mathrm{Abs}[\mathrm{Abs}[x] - \mathrm{Abs}[y]]$$

PostScript: {abs neg exch abs add 2 div abs 1 exch sub}

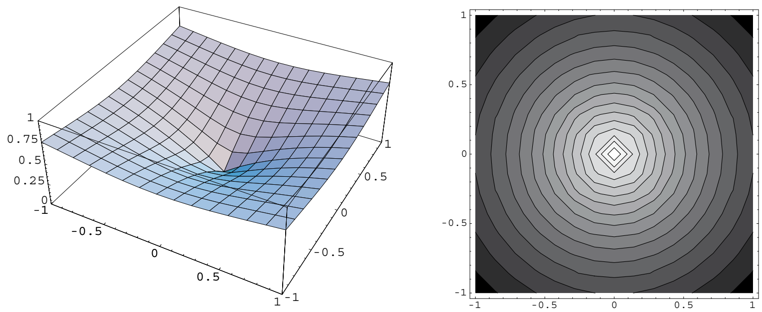
Model r2
wicker



$$z = 1 - \frac{1}{2}\,\mathrm{Abs}[0.6\text{`}\ \mathrm{Abs}[x] - \mathrm{Abs}[y]]$$

PostScript: {abs neg exch abs 0.6 mul add 2 div abs 1 exch sub}

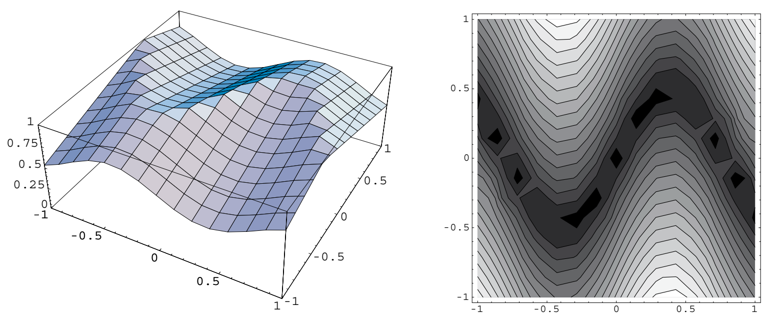
***Figure** 7 Models r1 and r2 SE*



$$z = 1 - e^{-\sqrt{x^2 + y^2}}$$

Model r3 peak

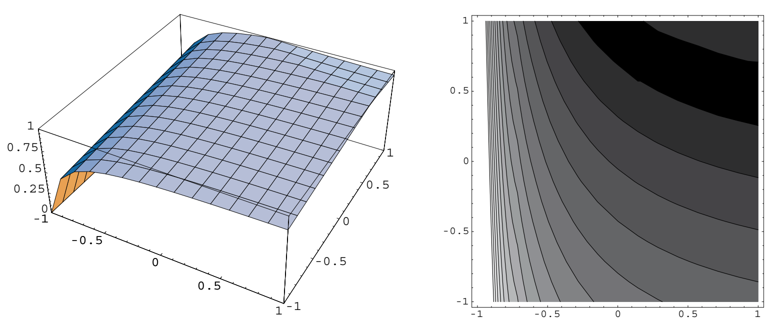
PostScript: {dup mul exch dup mul add sqrt neg e exch exp 1 exch sub}



$$z = 1 - \frac{1}{3}\,\text{Abs}\left[-y + \frac{1}{2}\,\text{Sin}[180\,x]\right]$$

Model r4 sinus

PostScript: {neg exch 180 mul sin 2 div add 3 div abs 1 exch sub}



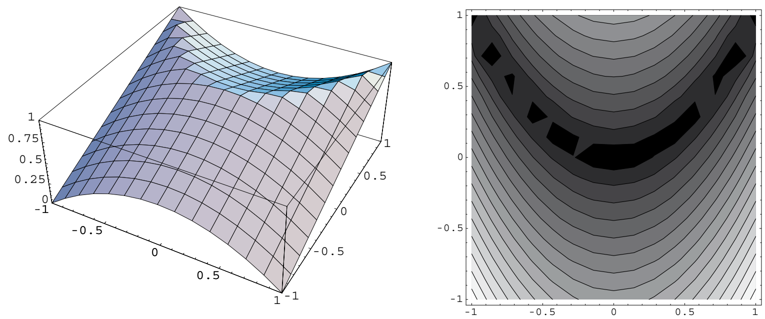
$$z = 1 - \frac{1}{10}\,\text{Abs}\left[\frac{1}{1.1` + x} - y\right]$$

Model r5 cake

PostScript: {neg exch 1.1 add 1 exch div add 2 div abs 1 exch sub}

Figure 8 *Models r3, r4 and r5 SE*

Model r6
wave



$$z = 1 - \frac{1}{2} \mathrm{Abs}[x^2 - y]$$

PostScript: {neg exch dup mul add 2 div abs 1 exch sub}

Figure 9 *Model r6 SE*

Figure 10 shows the application of all six SE models in the test pixel elements. A 4 lpi screen ruling and a 45 degrees angle have been applied. Each time when an algorithm retakes a screened gray level that has been already screened, a respective screen model does not have to be created again.

A number of columns and raws of pixels are defined by two parameters. This is the manner of creating a required matrix arrangement of pixels. The third parameter is used to define a number of bit per an pixel thus defining a number of possible grayscales of each pixel (28=256). The PostScript command image starts up arranging of pixels. Before its activation all of the abovementioned entities [35] should be present in the operation stack.

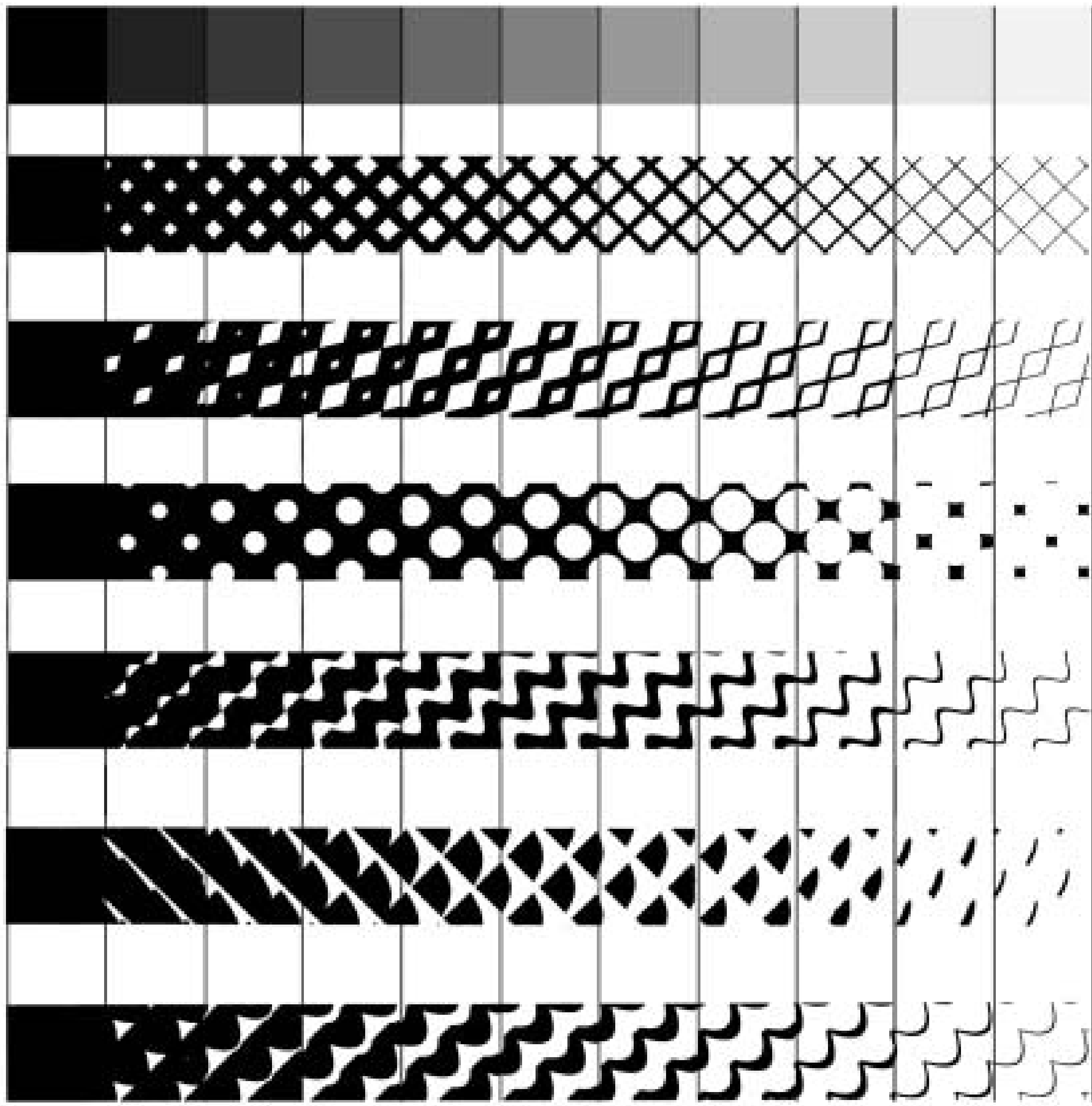
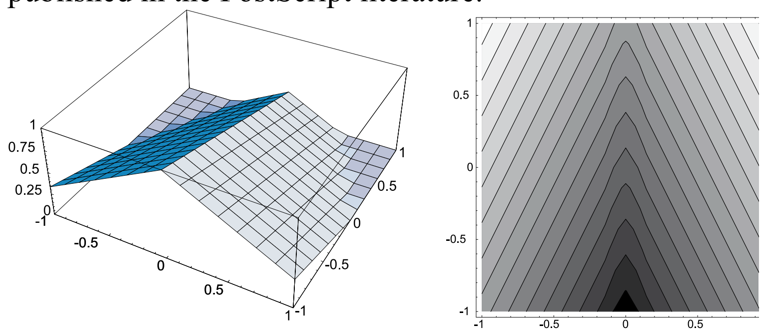


Figure 10 *Test image-based elements with the application of six new SE (4 lpi)*

The authors of the book have been applying this manner of screening on documents and securities since 1991. The most investigated is the sinus raster in two and three colour printing (Fig. 11). The new design approaches have been accepted in the reproduction of portraits and scenes on banknotes and maps.

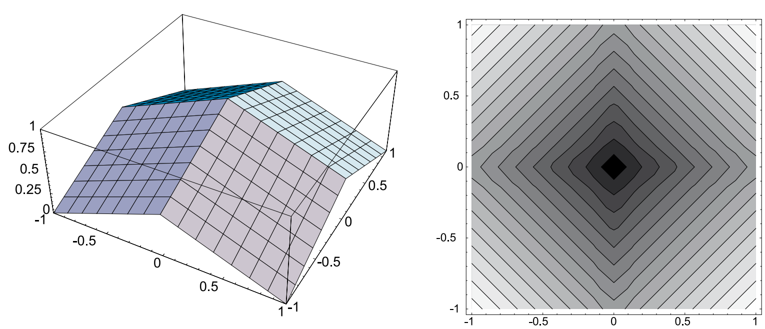
Figure 11 *Sinus screening*

The blackening area of SE has been limited by a square cell. This is causing distortions of forms already following the first contact with the barrier edge, and distortions continue until complete blackening. In the case of a rounded dot this event appears after 78% gray level, while in case of a triangular shape it appears already with the 40% gray level. The horizontal square shape has the best results, while severe interference with unrecognizable shapes has been found in trigonometric forms. The selection of SE depends on the material for depositing print, colors, color penetration into the paper, print screen ruling and SE dot gain. Figure 12 illustrates a growth of triangular and rhomboid shape published in the PostScript literature.



$$z = \frac{1}{3}\,(2 - y - 2\,\mathrm{Abs}[x])$$

PostScript: {neg exch abs 2 mul neg add 2 add 3 div}

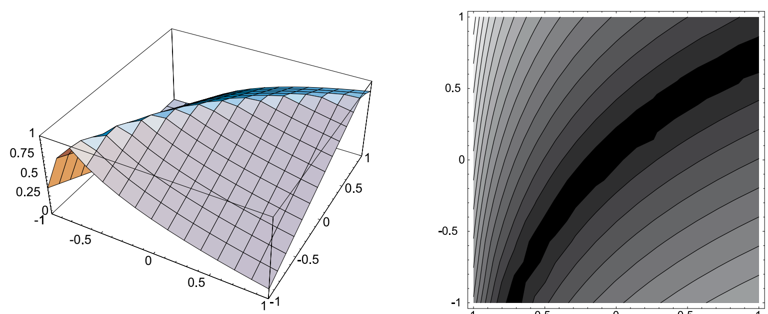


$$z = 1 + \frac{1}{2}\,(-\mathrm{Abs}[x] - \mathrm{Abs}[y])$$

PostScript: {abs exch abs add 2 div 1 exch sub}

Figure 12 *Triangular and rhomboid SE*

Screening as a mark of something of one's own, something individual and unique has for centuries been done by hand, by the hand of the artist through working on the metal engraving ground. This went on into the era of the etching on metal. Now, however, for all cases, computer printing is used. The engraving skills for the making of an original of documents and securities have been abandoned. New forms of SE (Figure 13) are created with mathematical expressions in order to individualise the reproduction, so as to obtain a high degree of protection of graphic impression. In monochrome printing this has been tried out already.



$$z = 1 - \frac{1}{2}\,\mathrm{Abs}[-y + \mathrm{Log}[\mathrm{Abs}[1.1\text{`} + x]]]$$

PostScript: {neg exch 1.1 add abs ln add 2 div abs 1 exch sub}

Figure 13 *Screen shape of engraving line imitation*

Figure 14 shows a parallel gradation for dot, triangular, engraving and square screen shape. It is important to note on which gray level a requested shape becomes distorted, sometimes implying that it cannot be used for the requested purpose. A darker grayscale enhances the impression of the shape negative.

Figures 15a, 15b, 15c and 15d show 4 different SE models, each shown in 12 different levels of gray. Brighter and darker pixels of the same model vary considerably, so one could get the impression that halftone screen elements originate from different mathematical relations (exclusively present on models 15b and 15c).

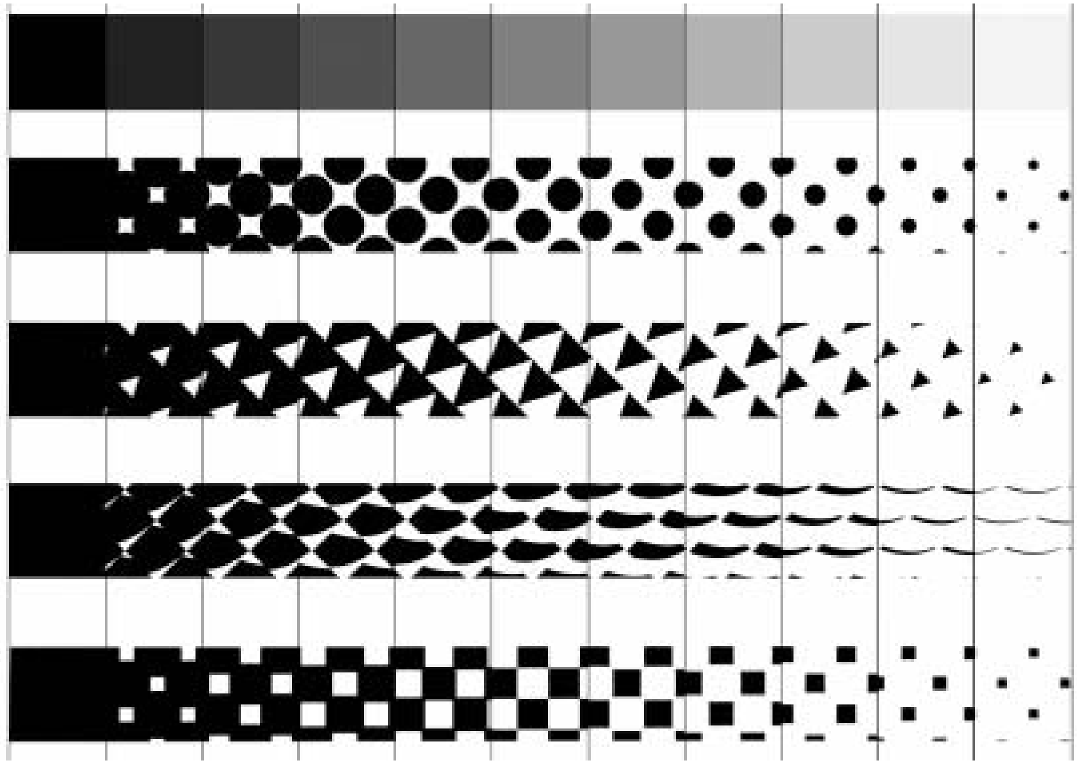


Figure 14 *TTest image-based elements with the application of 4 SE (4 lpi)*

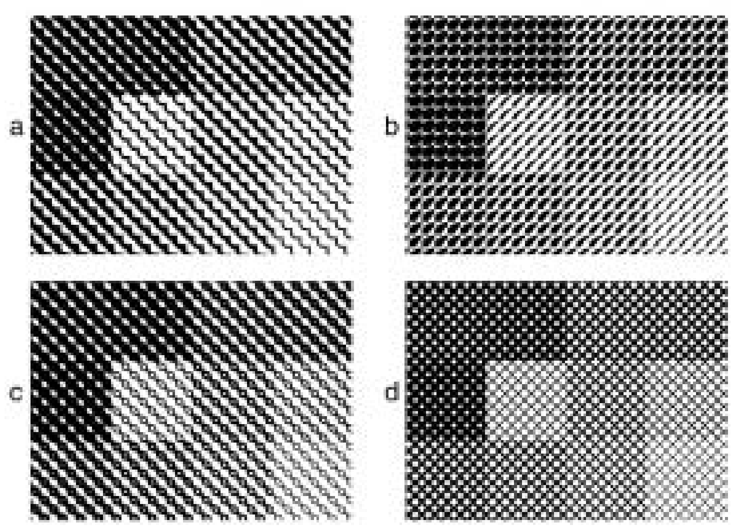


Figure 15 *Four different SE models in 12 different levels of gray*

A research on exponential forms was carried out with changing parameters appearing in the trigonometric part of the equation. Figure 16 shows results with partial change of exponent with *sin(5y)* and sin*(2y)*.

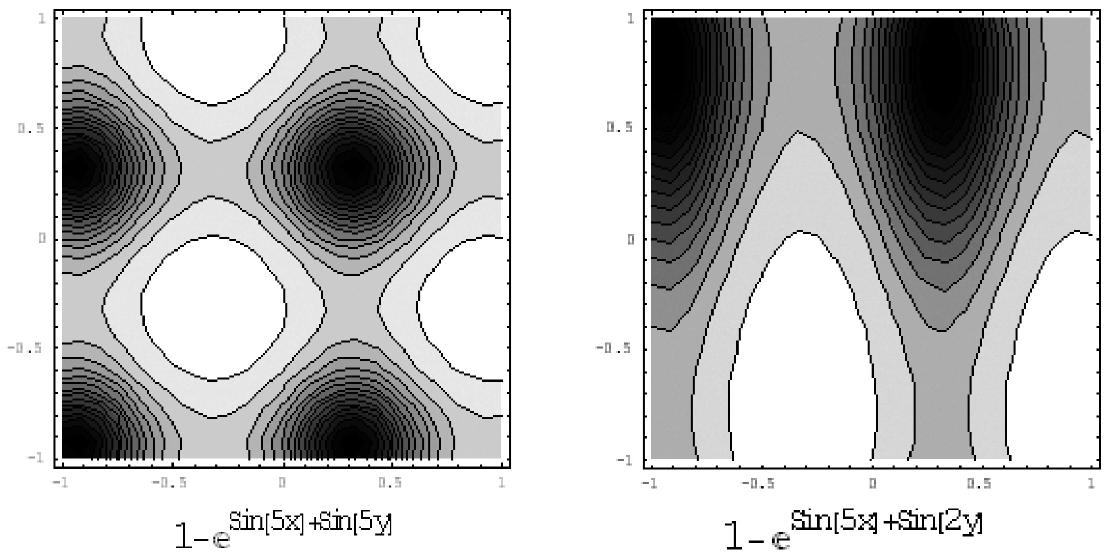
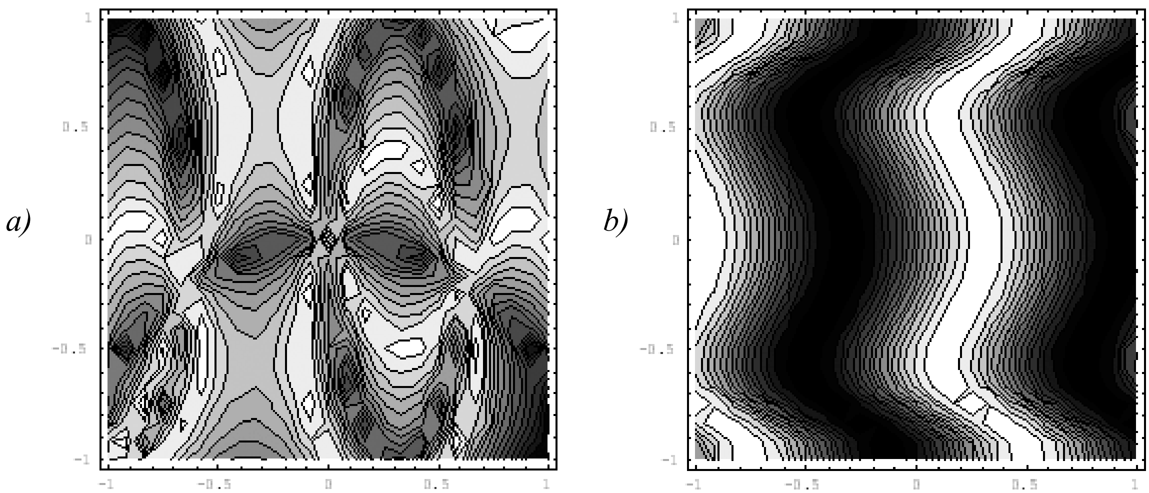


Figure 16 *Exponential SE forms*

Research on vibration shapes resulted in multiple arrangement operators such as square root, exponent, logarithm, trigonometry. Operators with absolute values are often used to protect from undesirable values that may result from the domain of defining a z growth function. Figure 17 shows a vibration form that has resulted subsequently in the implementing stage of a screen angle in unpredictable different forms.

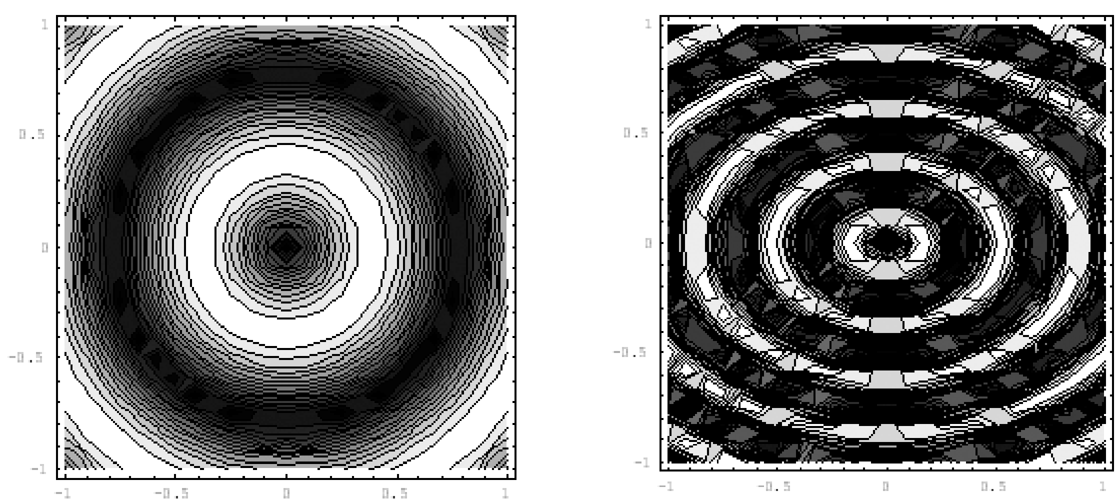
Ring-shape relations basically use a circle equation within a trigonometric form. The same applies to the ring distortion with a parameter or horizontal/vertical coordinates. Two relations have been given (Figure 18). The second one illustrates a SE with concentric rings within a single screen cell. This parameter has been subject to the random choice of size resulting in the experience of various new screen forms within a single graphic reproduction.



a) $1 - \text{Abs}\left[\sqrt{\text{Abs}[-y^2 + \text{Sin}[5x]]} - \sqrt{\text{Abs}[x^2 + \text{Sin}[2y]]}\right]$

b) $0.6 + \frac{1}{3}\,\text{Sin}[5x + \text{Sin}[5y^2]]$

Figure 17 *Vibration SE shapes*



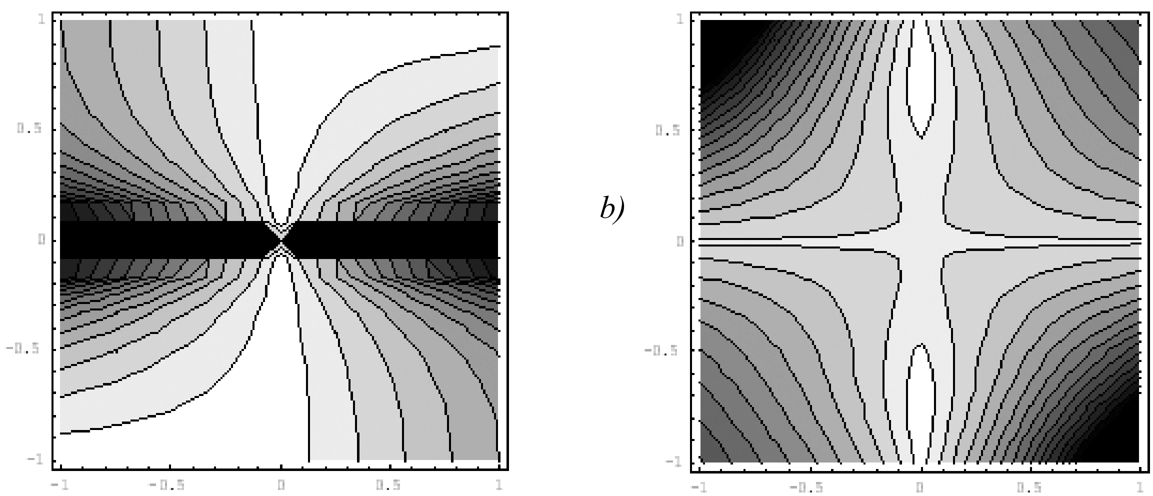
$\text{Abs}\left[\text{Sin}\left[4\sqrt{x^2 + y^2}\right]\right]$

$\text{Abs}\left[\text{Sin}\left[4\sqrt{10}\,\sqrt{0.5x^2 + y^2}\right]\right]$

Figure 18 *Ring SE shapes*

Fragmented forms wich filling up a graphic in reproduction, use the quotient value of coordinates x and y, as well as a product of their multiplication. Reciprocal coverage values are more easily tested in the PostScript due to parallel studying of allowed marginal screen cell conditions. Figure 19b shows a SE with a symmetric form. Rotating of a SE within a cell is achieved by unsymetric definition of relation of values of all coordinates. SE in the Figure 19a will not be symmetrical in the PostScript implementation, its cross-sections will be extremely expressed within the screen cell of the same pixel, although its dimension is larger than a screen cell.

a) *b)*

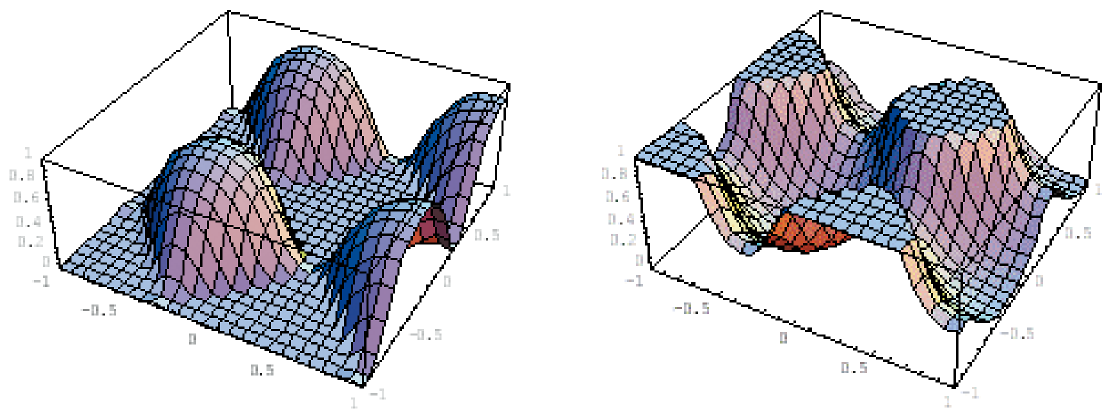


$0.7+\frac{1}{4}\left(x\,y-\mathrm{Abs}\left[\frac{x}{y}\right]\right)$ $\mathrm{Abs}\left[\frac{x\,y}{\mathrm{Abs}[2+x\,y]}\right]+\frac{1}{3}\,\mathrm{Sin}[\mathrm{Cos}[x\,y]+\mathrm{Sin}[y^2]]$

Figure 19 *Fragmented SE forms*

Relations describing a SE shape have limitations that may be seen in the 3D interpretation. A screen cell is defined within the area *x:-1, 1; y:-1, 1 ; z:0,1*. The most prominent bottle-neck in research of new SE is the *z* coordinate. The first correction should be performed through a 3D display. Figure 20 shows an exponential/trigonometric form.

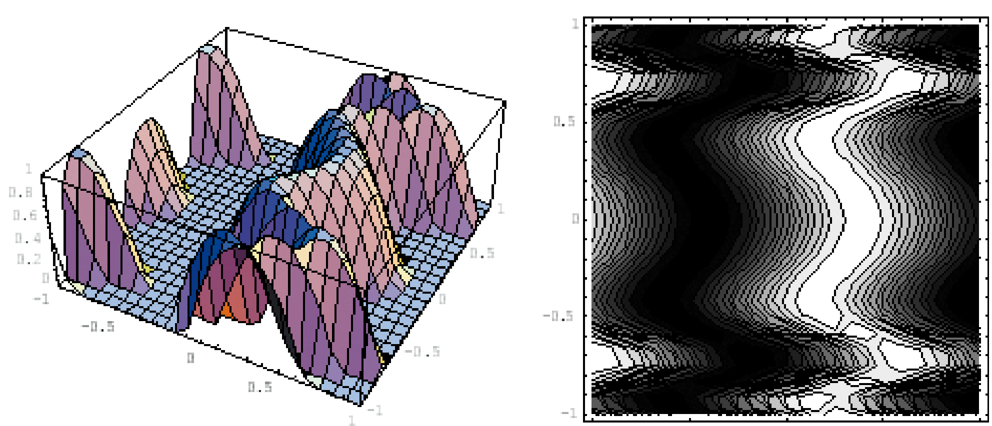
Figure 21b shows a vibration-SE with co-efficients that may be transformed successfully into a graphic application of a reproduced image. The relation skips a need for a divisor at the end of an equation, and has no initial progress coefficient. It has been illustrated in the Figure 21. It has



$1 - e^{\text{Sin}[5x]+\text{Sin}[5y]}$ $0.5\, e^{\text{Sin}[5x]+\text{Sin}[5y]}$

Figure 20 *3D display of contacting and overthrowing of a screen cell definition*

been illustrated in the Figure 21. Direct translating into the PostScript will not enable screening and graphic reproduction. This book proposes that interventions into a regular graphic environment be carried out in the very PostScript definition. The base of this vibration sine SE is a subject of future research on the application of protected printing of securities. In reference to numerical values of a skalar within an equation, this book proposes an introduction of an individualized size as a synergy between the graphic and its content.



$\text{Sin}[4x + \text{Sin}[9y^2]]$

Figure 21 *Vibration sine SE in contact with the upper and lower edges of a screen cell*

A screen imitating a sinus line has been often used in protected documents. Various definitions have been studied, in reference to the mathematical aspect as well as in the PostScript. Sinus cell behavior in the multicolor reproduction is identical to linear. Its moiré effect is twice lower. Vertical and horizontal axis are not in the moiré. A sinus screen is basically used for special effects only. Examples of the highest edition include reproduction of portraits on Swiss bank-notes and the front of the Croatian *Kuna* banknote. Multicolor reproduction with a sinus screen is shown in Figure 22.

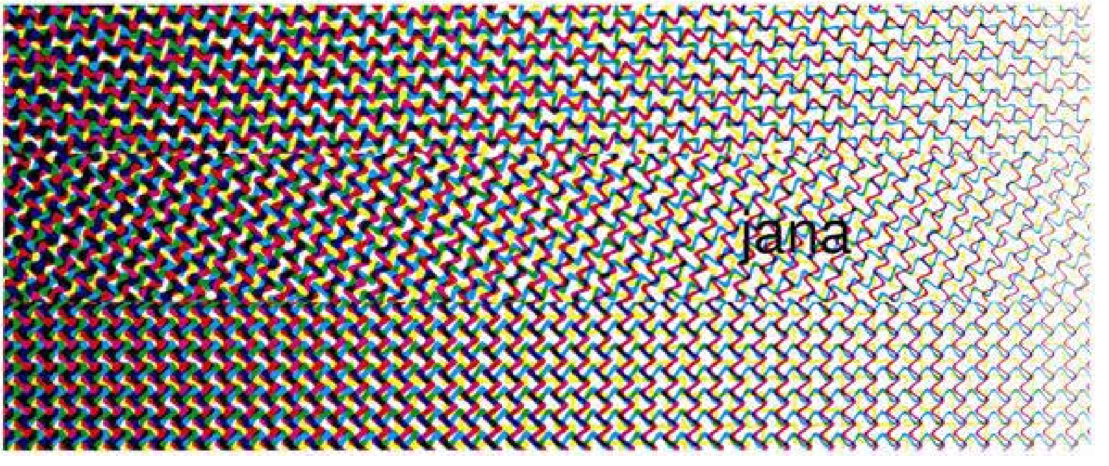


Figure 22 *Three-colored sine-reproduction with continued gradation*

Rotating a screen line causes turning of a screen cell and the screen element itself. This cannot be seen if a screen has a symmetric form, such as a conventional SE with a circular form. An inclination of a line has been illustrated with lace and crystal screen with a prominent SE turn. The illustration with a symmetric ring form within a screen cell in the cyan color (Figures 23 and 24) has been given in order to avoid a change of form in the course of turning an inclination of a screen line. Each color has been associated with a different SE form: lace, ring and crystal; respectively for cyan, magenta and yellow color.

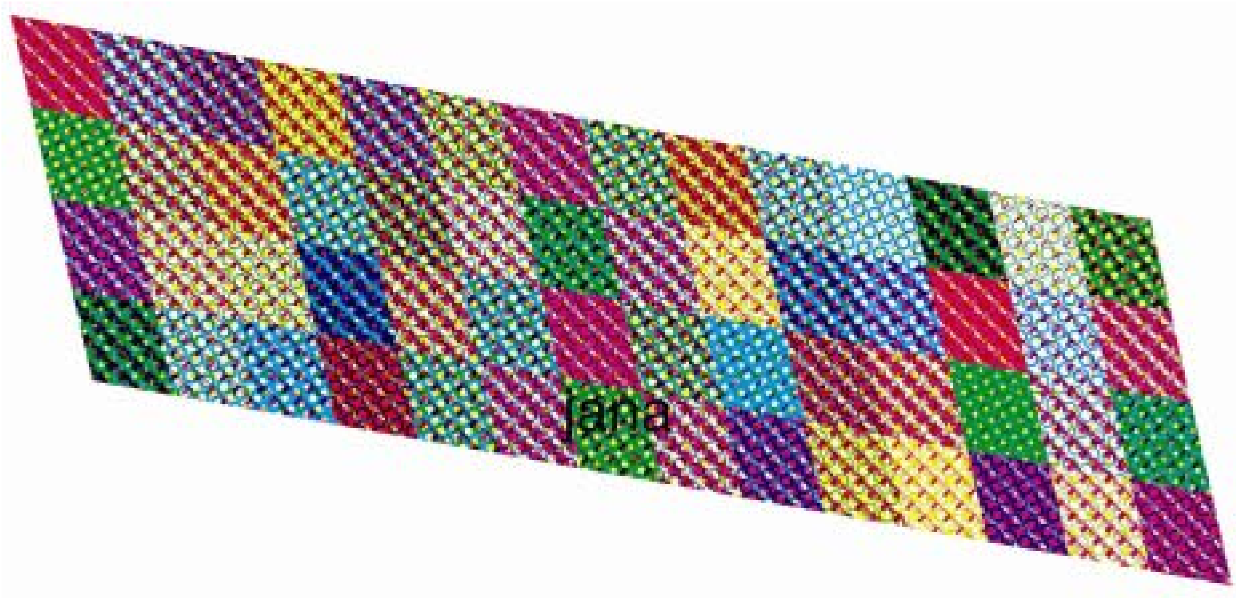


Figure 23 *Disrupted SE with various screen forms (10 lpi)*

Figure 24 *SE cross-sections on pixel edges (4 lpi)*

Mutants

A contemporary graphic product is based on the end user requirements and this means that it must be individualized. Digital printing stresses its advantage as to the possibility of individualized printing. Research work described in this book has given individual mutant screening of each image element in a specific manner (Figure 25, 26, 27, 28). The advantages are in the application that must have a higher level of individuality, the quality of not being able to be repeated and dependence on the information contents that the graphics and graphic design carry. In case of reproducing a color image the possibility is stressed to design programmed joining of different color channels with choise of screen element. As there is a growing trend to mix process and spot inks in the same graphic page, the multiplied joining of screen element shapes opens a new area of graphic application. It is proposed to use positive and negative deformation of SE from the same set in the same position for different color channels.

It has been determined that the numerical parameter values in the algorithm given as a classical mathematical formula converted into PostScript are different from the PostScript executive formula. This has opened the area for studying the screen element generating during bitmap forming in the printed form (Figure 29).

$$0.666667\,(1.5^x - y^2)$$

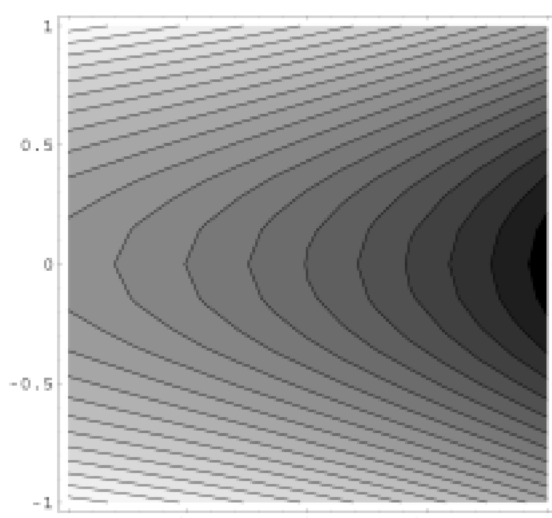


Figure 25 *Mutant screen element - code name M65*

$$0.333333\,\mathrm{Abs}\left[e^{x^4} - y^2\right]$$

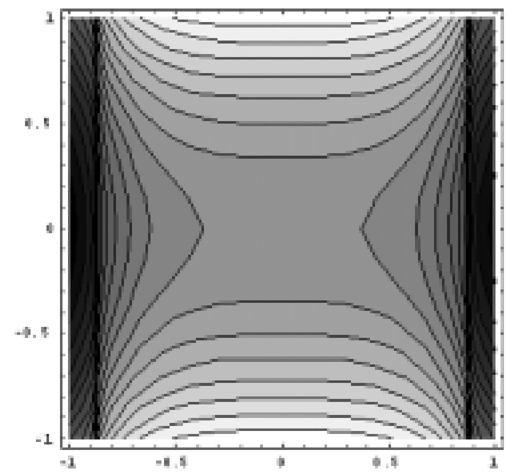


Figure 26 *Mutant screen element - code name M66*

$$\frac{1}{4}\,\mathrm{Abs}\left[e^{x} - y^2\right]$$

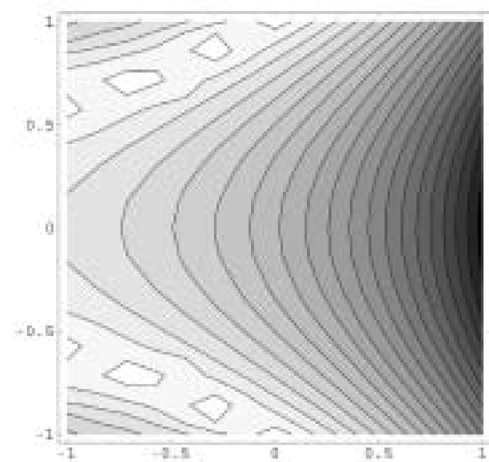


Figure 27 *Mutant screen element - code name M67*

$$0.666667\,\mathrm{Abs}\left[\mathrm{Sin}\left[\mathrm{Abs}\left[0.25^{x^2} - y^2\right]\right]\right]$$

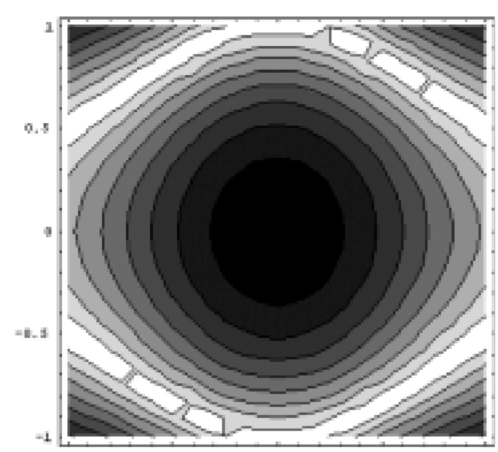


Figure 28 *Mutant screen element - code name M68*

Figure 29 *Bitmaped Mutant SE - M65, M67, M68 after RIP-ing phase*

3. Experimental work with new screen elements

The halftone screen element shape that has been created by screening with PostScript tools is of regular clean form, border and blackness . Its interpretation may be seen on the computer screen. Most often after printing this screen element has a gain, the ink is absorbed, it also spreads and all of this creates unwanted covering capacity interpretations. Deviating of the sharp bitmapped shape while it is in the computer depends on several parameters that may be pinned down to the relation between color, toner, ink and materials they are applied on. Coated papers have different absorbing results; they are less likely to lose color in paper. In this direction there is discussion about color viscosity, stickiness parameters. Printing techniques, from offset, screen printing and all the way to more contemporary digital printing variants are separate research topics on the halftone screen element deformation and covering capacity changes. Spreading of ink is extreme in inkjet printing on art paper, paper types meant for other techniques, as for instance intaglio, and those that have special prepress procedures. In order to comply with artists and to have impressive images printed on such sophisticated or manually produced paper there is need to shift to individual solutions where the very skill of the graphic designer provides satisfactory results. Artists simply wish to have their works of art carried out on paper they choose themselves.

Many studies on the halftone dot gain give recommendations how to measure – which methods and instruments to use, all with the goal to achieve the same value between the set dot gain and the printed one. Recommendations are given without sufficient stress on the experiment's borderline conditions, experimental guidelines, and the area of material parameter definition – ink as well as paper characteristics. To give an example: digital printing with ink on coated paper compared to inkjet printing on voluminous paper is so completely different that it is not advisable to apply the same recommendations.

The conventional discussion describes spreading of the printed halftone dot leading to greater dot gain. Experience based on digital printing with dry ink lead us to make the conclusion that dot gain does not alter neither with the dissipation of ink particles, nor with the altering of the screen dot form.

3.1 Mutant screen element coverage

The printed screening has an changed screen element image, and the element itself does not have clearly defined borders. This occurrence applies to all screen form types, and also to conventional circle SE. The prominent deformation does not occur only with small screen ruling, and it is the always present disturbance with screen rulings whose value is above some ten or so lpi. The SE periphery disappears gradually towards the white surface on which the ink is applied.

There is sense in measuring the SE circumference only in the digital (PostScript) SE display, i.e. before the image comes in touch with the material, i.e. the printing form or print of any kind. In such displays it is possible to measure correlation between the path length of SE circumference and coverage. The print does not have clearly defined borders from SE so it is not advisable to measure circumference. It is possible to measure coverage and make comparisons between them. Coverage before printing and coverage after printing.

Print scanning is illustrated with several different kinds of precise information. The resolution of scanning 600 dots per inch (dpi) for screen ruling testing of 5 lpi is good enough, and there is almost no difference when scanning was carried out with 900, 120 or 1800 dpi. The finer SE environment structure provided greater preciseness of the grayscale, as well as better imitation of its grayness. The space of analyzing the screen cell, and thereby the screen element is from 0.6 mega pixels (600 dpi) to 7 mega pixels for 1800 dpi. Thus the reproductions scanned in this manner as well as the SE have the goal to determine measure and interpret dot-gain appearance for each new screen form. It is not possible to determine precisely the position of one screen cell, so measurements are carried out in a wider area. For instance, 36 to 45 screen cells are observed for 5 lpi, and for 75 lpi the number is between nine and eleven thousand. Due to possible imprecise choice of borders in the SE print, the proposal is to cover a larger number of cells; from 36 to some ten thousand cells.

With higher screen rulings, there is strong closeness of the gray SE periphery. With small screen rulings there is pure whiteness, and in higher screen rulings the whiteness around the screen element is assigned to the gray SE environment. The SE borders pull out the color from their close-by environment. When it is a case of larger screen ruling, the color is taken from the very center of SE, and this means that in high dot gain there is no totally black color, and that applies to the SE center as well. With such screen rulings there is also total shape deformation of SE. The shapes transit into the central stacking and in it is then senseless to introduce new SE, except for linear shapes, such as the straight line itself and the sinusoidal line. The mentioned effect is almost non-dependable on the printing technique because we can find it in printed forms such as film or CTP. Using of new screen elements in graphic design and securities makes sense only when the screen rulings are extremely low and well noticeable to the human eye, and where relative spreading of ink is not great.

Figure 30 shows the M68 structure with 50% coverage after RIP-ing with fully clean borders for which the circumference length may be measured and the black-and-white coverage ratio.

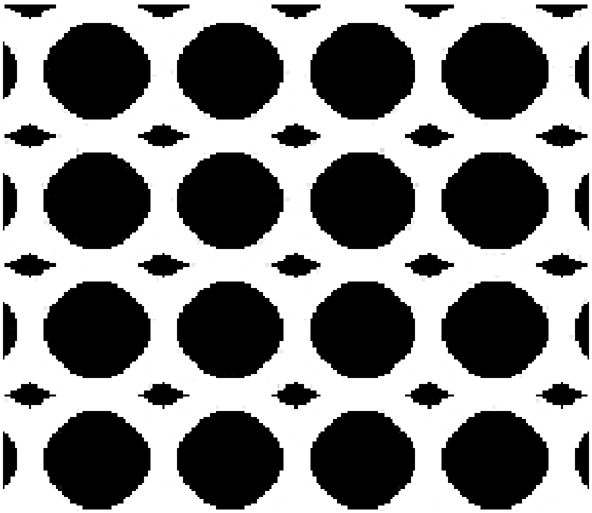


Figure 30 *50% M68 coverage after ripping and before printing (clean SE borders)*

Producing of the printing form and the printing procedure have caused SE gain at borders and this is for the same example given in Figure 31. In order to determine the print coverage, prints have been scanned with 900 dpi, 1200 dpi and 1800 dpi, with the same number that was used in making the bitmap of the individual images. In this way it was made possible to study spreading of ink in the SE environment, as it is possible to read out the highlight value for each scanned pixel, and thereby for the dot gain as well. The total of all values scanned pixel highlights for the researched area divided by the total number of observed pixels gives the mean highlight value for the given area. The print in digital printing by XEIKON 32 of the mutant SE – M68 with 20 lpi is shown in Figure 31 in two enlargements. The upper image part covers the wider area, and the lower part shows the area of one screen cell.

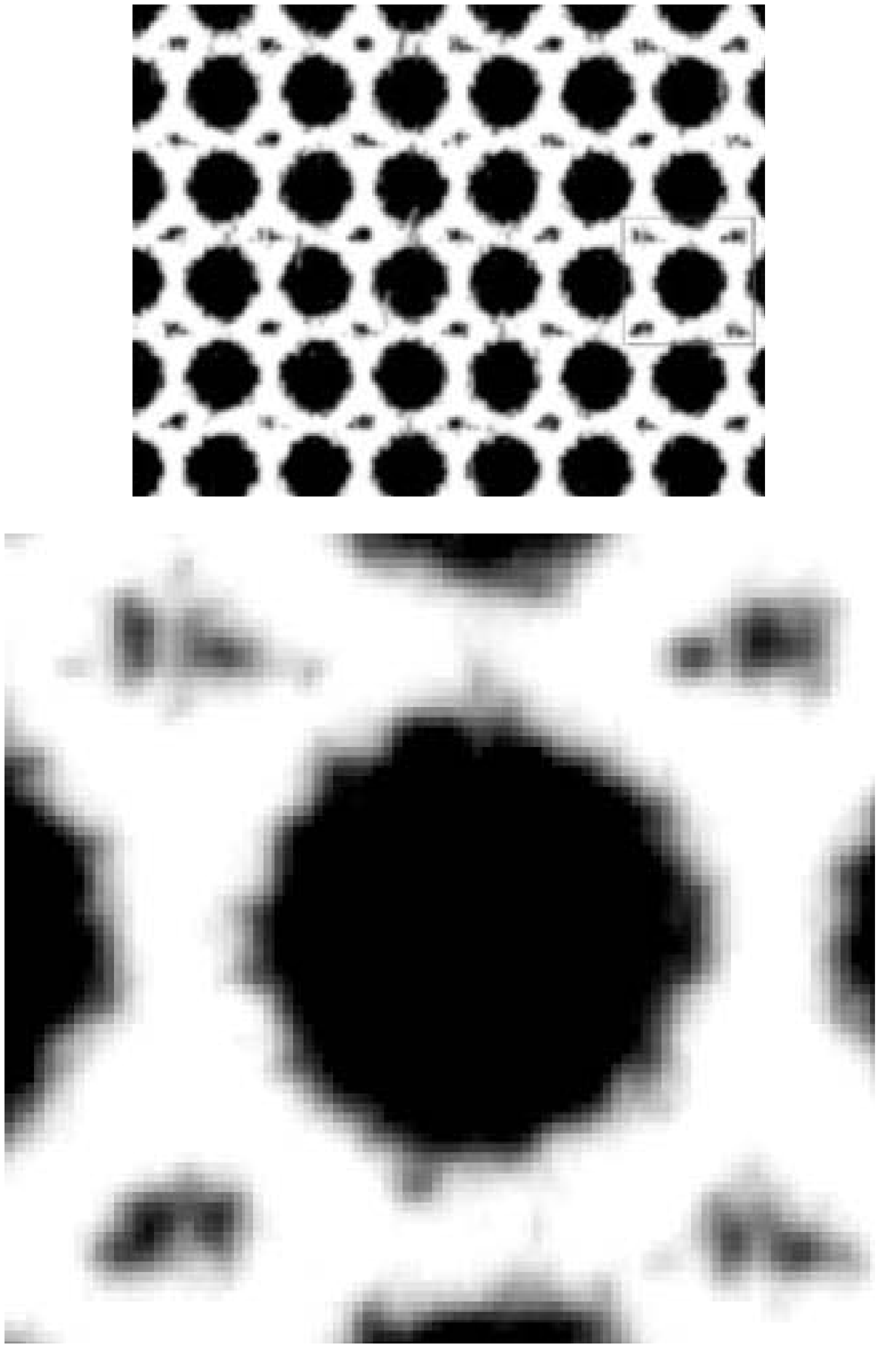


Figure 31 *Screen element M68 border dot gain after printing (print scanning)*

The dot gain values of certain SE border parts in Figure 31 are given in 10 steps and especially the coverage of 100% and 0%. There are differences in total coverage between the riping phase previous to printing form production and after printing. The results of this measuring are given for M68 in Table 1. The first columns in Tables 1 and 2 show screen ruling (L20 lpi) on basis of which this test was made and the set coverage of 10, 30, 50, 70 and 90% (abbreviation Xla20 10). The second column is the number of the raster print scanned elements that have fallen into the dot gain and coverage calculation.

File	**Nr. pixels**	**black**	**white**	**1-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-99**
Coverage				Nr.pixl 1-10% cover.									Nr.pixl 90-99% cover.
XLa20 **10**	518400	16002	433195	9458	7167	5622	5131	4651	4525	5323	6732	8113	12481
XLa20 **30**	518400	105578	292951	11382	8623	7527	7560	7602	8266	9752	12691	16839	29629
XLa20 **50**	518400	173709	142733	15537	13147	12235	12995	12709	13633	15549	20695	28497	56961
XLa20 **70**	518400	246032	1793	26493	20800	18723	19332	18095	19464	23448	32918	50316	40986
XLa20 **90**	518400	380941	0	29085	24844	23312	23812	19080	12501	4217	603	5	0

Table 1 *Number of pixels after scanning with the rate in coverage*

The white area is replaced with gray area. With a high coverage percentage the white area disappears, and the black area diminishes extremely. The greater the set coverage, the bigger is color dispersion from the determined center of cluster. The gray areas are larger depending on the set coverage values. Gradually the gray areas totally close the white area.

File	Nr. pixels	Black %	White %	1-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-99
XLa20 **10**	518400	3.080	83.563	1,8245	1,382	1,084	0,9898	0,899	0,8729	1,026	1,2986	1,565	2,407
XLa20 **30**	518400	22.366	56.510	2,1956	1,663	1,452	1,4583	1,466	1,5945	1,881	2,4481	3,248	5,715
XLa20 **50**	518400	33.508	27.533	2,9971	2,536	2,360	2,5068	2,451	2,6298	2,999	3,9921	5,498	10,987
XLa20 **70**	518400	47.459	0.345	5,1105	4,012	3,611	3,7292	3,498	3,7546	4,523	6,3499	9,706	7,906
XLa20 **90**	518400	73.483	0	5,6105	4,792	4,496	4,5934	3,680	2,4115	0,813	0,1163	0,001	0,000

Table 2 *Relative rate in coverage – percentage of the total pixel number in coverage percentage*

A parallel display of coverage for the mutant M68 before the print (RIP C/B) is given in Table 3 and following digital printing where parts of all gray areas in SE environment and within the screen cell have been included in the calculation.

file	coverage %	print coverage gray borders	deviation %	coverage RIP C/B	deviation %
L20 **10**	10	9,7107	-0.2893	10,3840	0.3840
L20 **30**	30	29,6882	-0.3118	30,0290	0.0290
L20 **50**	50	47,9417	-2.3118	49,9269	-0.0731
L20 **70**	70	69,6083	-0.3917	69,9331	-0.0669
L20 **90**	90	92,7116	2.7116	90,1436	0.1436

Table 3 *Coverage following the riping process and the print coverage*

Deviations for 20 lpi screen rulings are very small with mutant M68. The image is brought down to the minimal «zero» deviation after print scanning.

It is advisable to check each new screen in several printing techniques in order to see the screen element structure, dissipation of ink and toner and SE deformation after printing (Fig. 32, Fig. 33).

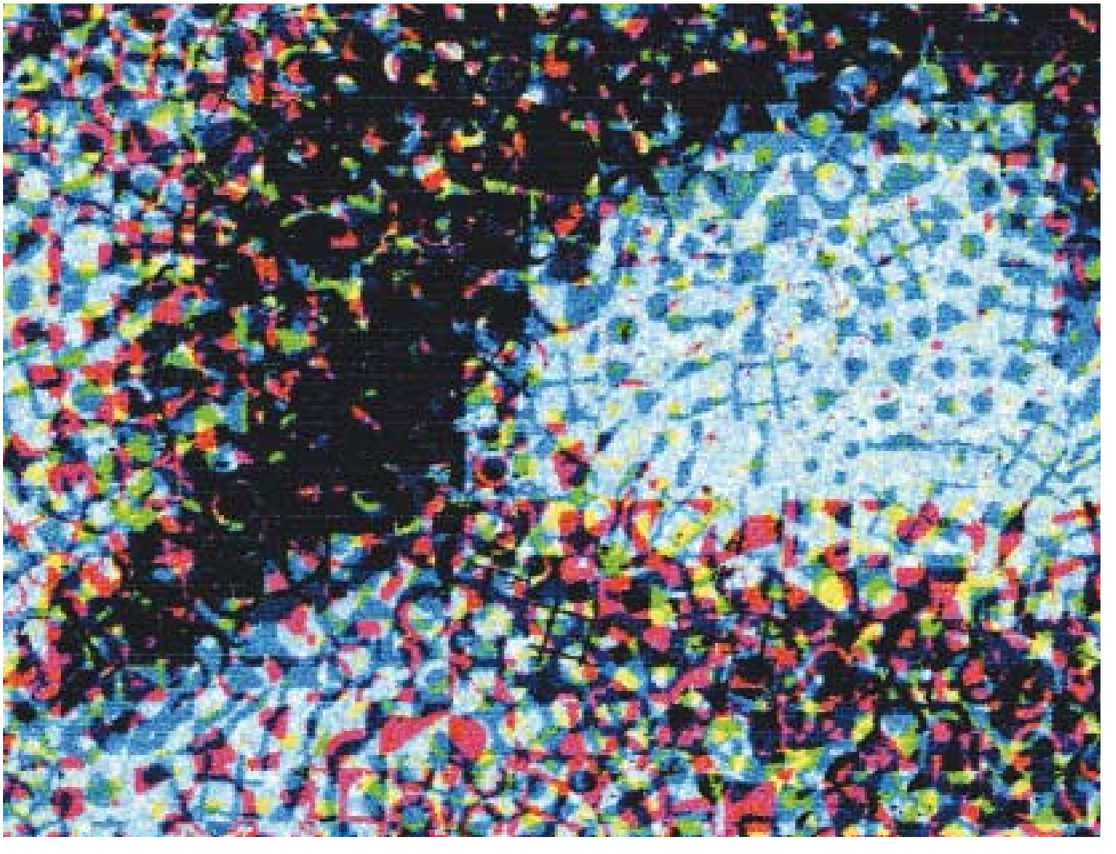


Figure 32 *Highly adjusted metal coated paper for inkjet printers (Epson)*

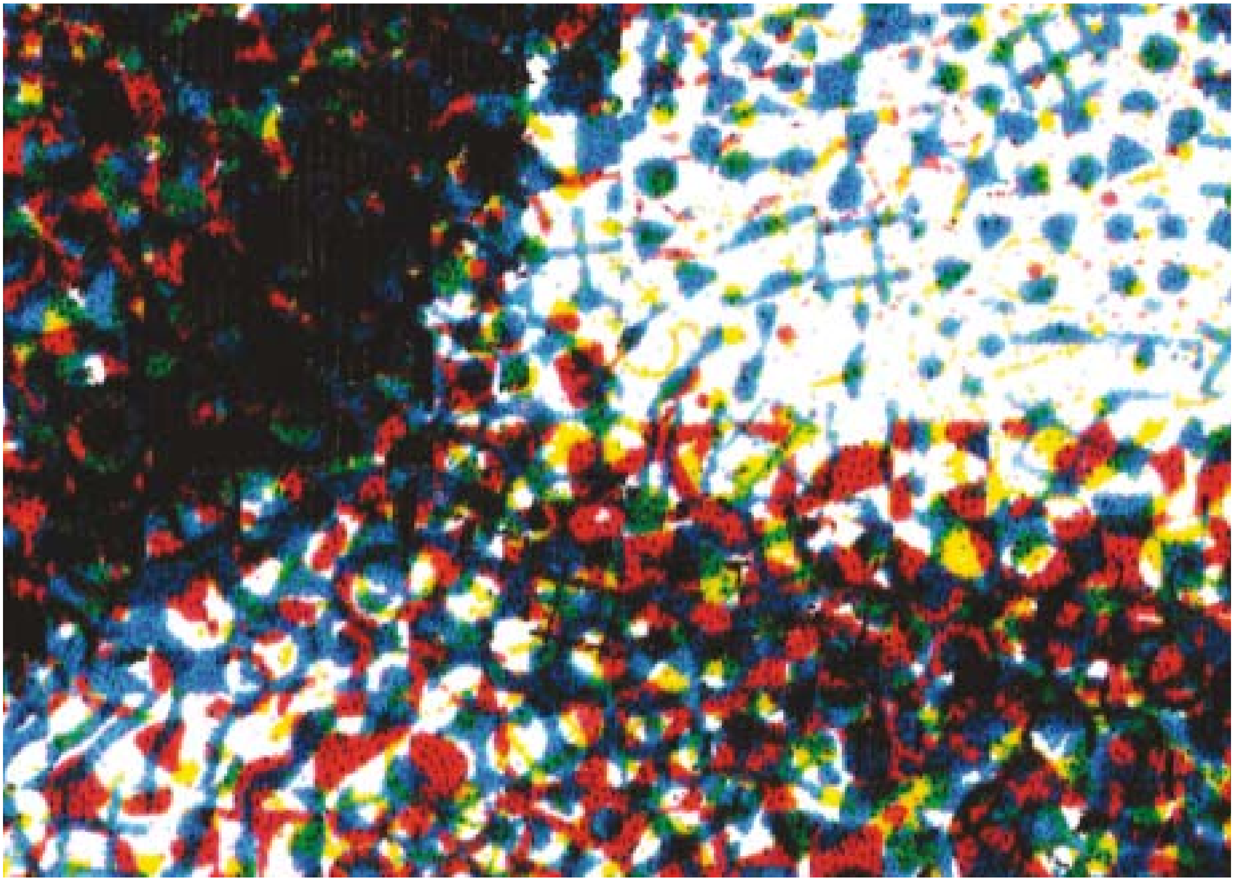


Figure 33 *Ink on absorbing paper when applying new SE on ink jet printerE on ink jet printer*

3.2 Printing of round, square, lace and crystal screen element

The gray area is an integrated coverage of square shaped area of scanned individual ink particle pixels that are dispersed on the SE borders inside the screen cell. The round SE of a 30 lpi screen ruling is shown in 70% coverage on figure 34.

The pure white area is less than 22%. Theoretically, the neighboring SE in the neighboring cells is touching at 79.5%. Print measurements with scanning at high resolutions have given the initial touching of neighboring SE. For the same coverage and different printing techniques it is concluded that such a case depends most of all on the screen ruling.

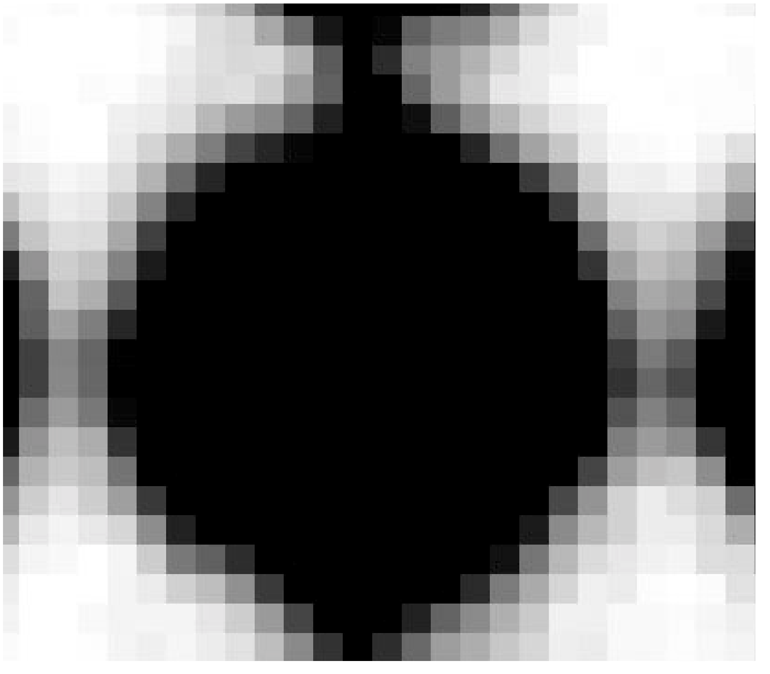


Figure 34 *The round screen element on 600 dpi, 30 lpi 900 dpi on ink jet printer*

The whole screen element illustrates closing and linking of certain SE, and this is already at 70% coverage for 30 lpi. Coverage measurements for a 5 lpi screen ruling are given in Figure 35. Deviations are minor and amount is up to -2% to 6% for different SE (circle, square, lace and crystal). The joint display of all the four SE is in favor of the assertion that the screen form itself is not crucial in the coverage preciseness if the print is carried out with small screen ruling on a printer that is declared to be 600 dpi (all examples in the chapter have been riped with 900 dpi).

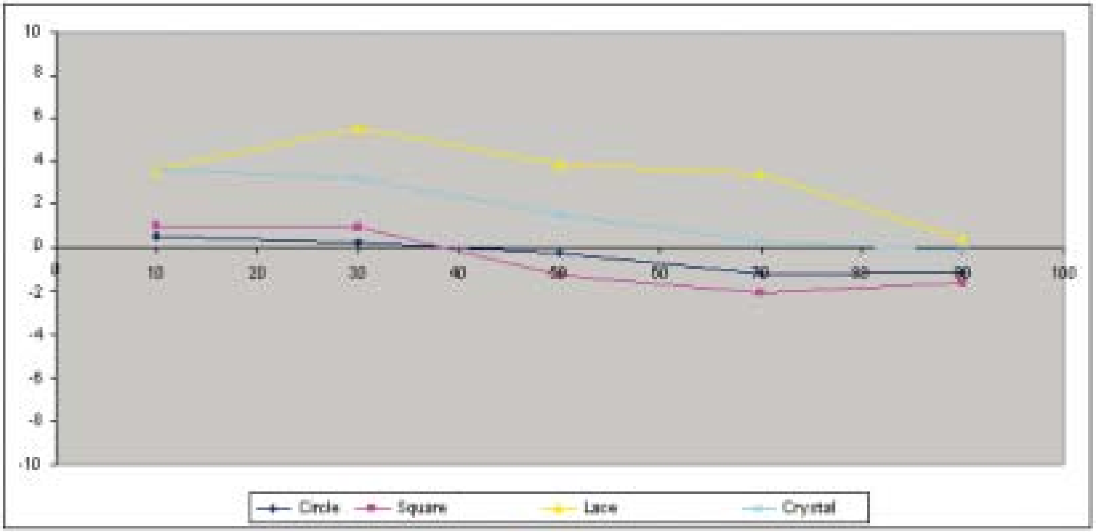


Figure 35 *Screen ruling 5 lpi. Deviations in coverage for round, square, lace and crystal SE depending on the set coverage*

Round SE on 30 lpi screen ruling has deviations in total dot gain up to 2% on a 600 dpi printer. There is even less deviation with square SE. However, for the printer with such a low resolution it is not possible to create the lace and crystal form SE in the original form.

coverage % **Printer 30/900**	print coverage% Circle	deviation	print coverage% Square	deviation
10	10,322	0,3228	11,2165	1,2165
30	28,533	-1,4670	30,9179	0,9179
50	47,858	-2,1414	50,6904	0,6904
70	69,385	-0,6141	70,4618	0,4618
90	90,251	0,2517	90,2704	0,2704

Table 4 *Deviations in coverage for circle and square SE when applying a 600 dpi printer, 30 lpi*

Due to 30 lpi a cell is formed with 401 gray steps but this is too small for designing these SE. The crystal screen (Figure 37) loses its form completely and does not resemble the basic design in any way. It may be concluded that new screen forms with dispersed shape have application only with low screen ruling, for instance in jumbo posters.

coverage % **Printer 30/900**	print coverage % Lace	deviation	print coverage % Crystal	deviation
10	14,9026	4,9026	11,6971	1,6971
30	39,6803	9,6803	47,4676	17,4676
50	55,6688	5,6688	63,1776	13,1776
70	76,3315	6,3315	79,3640	9,3640
90	93,7950	3,7950	96,2171	6,2171

Table 5 *Deviations in coverage for lace and crystal SE form when applying a 600 dpi printer, 30 lpi*

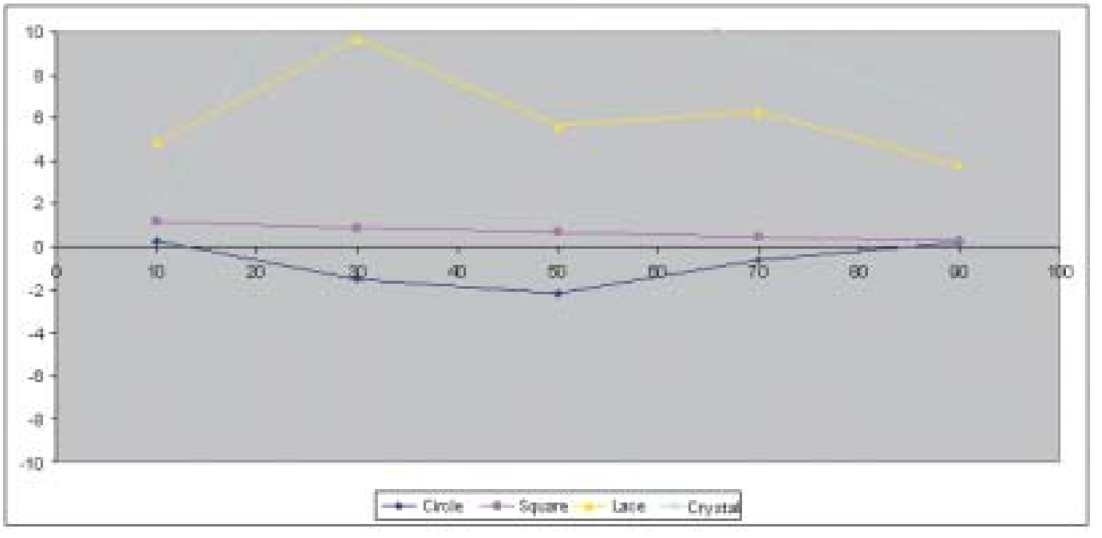


Figure 36 *Screen ruling 30 lpi. Deviations in coverage for round, square, lace and crystal SE depending on the set coverage*

Major deviations in lace and crystal SE on a 600 dpi/30 lpi printer are present with inkjet printers and also on various types of material. Newer 2400 dpi printers render better results, but only on paper and foil that are declared for such printers.

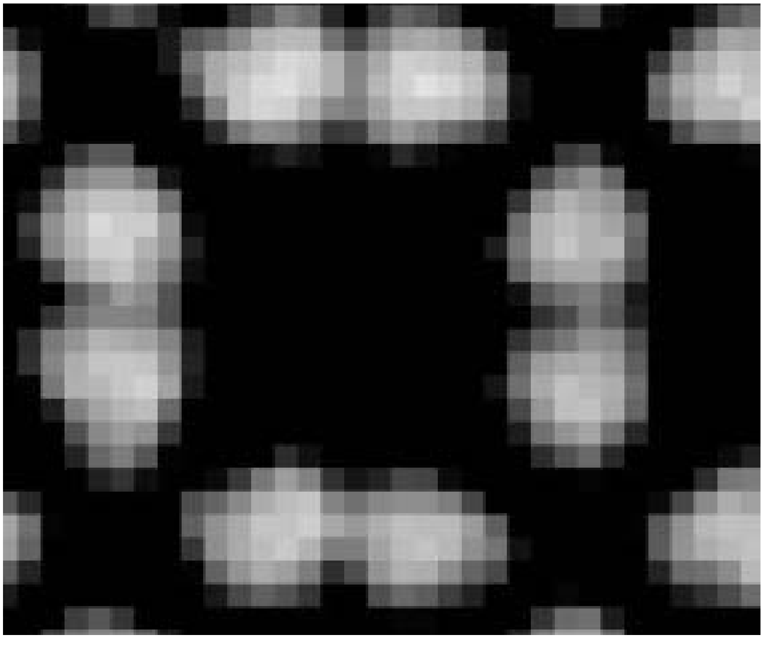


Figure 37 *Crystal screen on 600 tpi / 30 lpi printer, 70% coverage*

There is total closing in the white area. The screen form stop to be recognized, although the total image refers to only one SE. Only by recognizing the shape it may be assumed that it is a case of crystal SE. For a printer printout, the crystal SE is not applicable for higher screen rulings. Problems may arise also in respect to achieving the set coverage. Adjustment of highlights may be brought to segment adjusting and this would provoke further deformation of SE forms.

3.3 Printing of ring, negative rhombus and rhombus SE

Digital printing has proved to be interesting and dominant in print individualization. It is about applications with special stress on the stochastic layout of screen form choice, screen ruling and stochastic choice of the angle for screening advance.

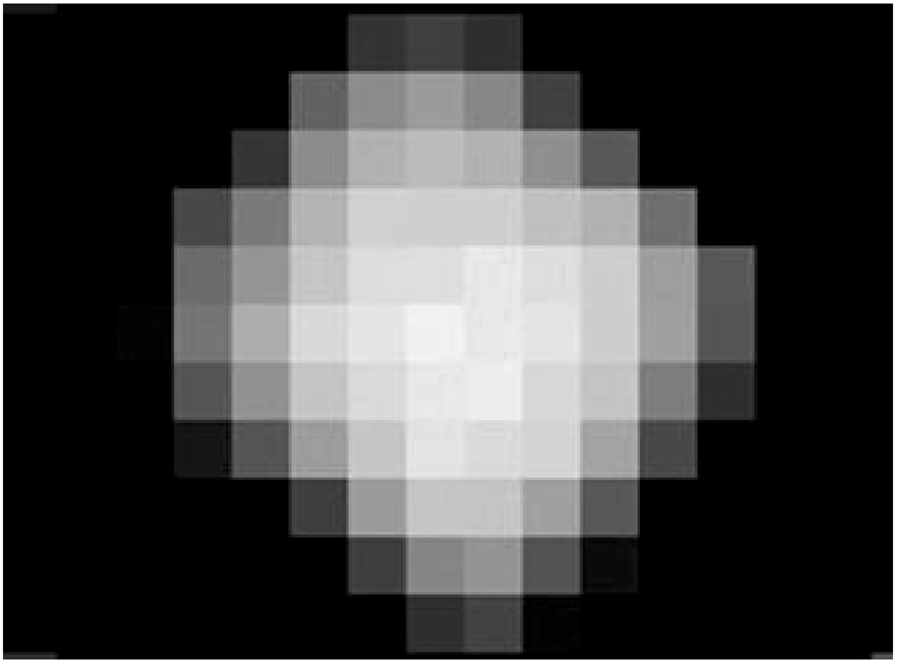


Figure 38 *Negative rhombus environment at 70% coverage for a printer printout 30 lpi/900 dpi*

In the negative rhombus display (Fig. 38) there is closing in almost all the white area surface. The ring-like form, negative ring and negative circle have good coverage results with a deviation of about 1 %. The negative rhombus screen form has greater deviations. It is characteristic that seems like altering of shape from linear structure to transient perforated square structure.

coverage% **Printer 5lpi/900dpi**	print coverage % negative rhombus k4Z	deviation	print coverage % negative circle K3Z	deviation
10	13,5790	3,5790	10,5683	0,5683
30	31,8562	1,8562	30,2361	0,2361
50	50,8873	0,8873	51,6361	1,6361
70	70,8018	0,8018	72,5776	2,5776
90	89,6967	-0,3033	90,8949	0,8949

Table 5 *Deviations of coverage with print of 'negative rhombus' and 'negative circle' for a 5 lpi/900 dpi*

coverage% **Printer 5lpi/900dpi**	print coverage % negative ring K2Z	deviation	print coverage % ring K1Z	deviation
10	10,6784	0,6784	11,3711	1,3711
30	29,9274	-0,0726	30,9053	0,9053
50	50,3212	0,3212	49,8725	-0,1275
70	69,5650	-0,4350	69,8820	-0,1180
90	89,1663	-0,8337	90,5812	0,5812

Table 6 *Deviations of coverage with print of 'negative ring' and ring-like screen for a 5 lpi/900 dpi*

Deviations as to print coverage in respect to the set values are small (Fig. 39). They may be corrected in graphic prepress or in adjusting toner coating and the printing press printer calibrating. This is the case with small screen rulings where the screen element is created out of several hundred basic ink dots. For higher screen rulings on the same printer the deviations are not controlled well. Measuring shows that the instability in coverage varies. If the coverage preciseness were to be adjusted in one part, the coverage in the other part would be put into disorder.

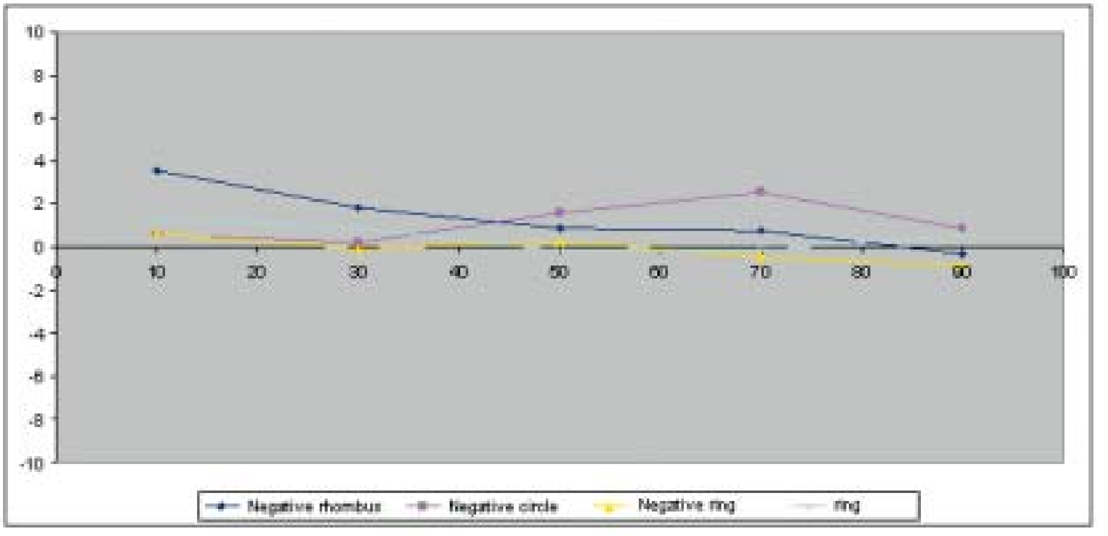


Figure 39 *Deviations of coverage with printer prints for a 5lpi screen ruling*

coverage% **Printer 30lpi/900dpi**	print coverage% negative rhombus p4Z	deviation	print coverage% negative circle p3Z	deviation
10	9,5670	-0,4330	9,3377	-0,6623
30	42,9851	12,9851	29,8513	-0,1487
50	57,5475	7,5475	54,5950	4,5950
70	73,1300	3,1300	73,8632	3,8632
90	91,8807	1,8807	95,4541	5,4541

Table 7 *Deviations of coverage with print of 'negative rhombus' and 'negative circle' for a 30 lpi/900 dpi*

Printers behave differently so that measurements are different for each experiment. There is no stability in larger screen rulings. This instability may be allotted to an insufficient number of screen cell divisions, i.e. and insufficient number of gray steps. This number is defined with the printer screen ruling and printer resolution quotient square. At high resolutions that we have with phototypesetters or CTPs, the stability is well controlled so that deviations of given and printed coverage may be adjusted in the phase of making the printing form or later during the process of making prints.

Deviations of coverage measured on a print with a screen ruling of 30 lpi are greater for negative screen shapes, and for shapes with double outlines. Rotating of screening direction adds and takes away coverage in the 30 lpi print. However, it is only the case for greater screen rulings where the gray scale value of SE is diminished. The screening angle has not added or taken away coverage in screen rulings up to 10 lpi for printers with toner printout.

coverage % **Printer 30lpi/ 900dpi**	print coverage % negative ring p2Z	deviation	print coverage% ring p1Z	deviation
10	11,6968	1,6968	11,2248	1,2248
30	38,1099	8,1099	47,0732	17,0732
50	55,7651	5,7651	62,3005	12,3005
70	72,3553	2,3553	76,4538	6,4538
90	91,2315	1,2315	93,2995	3,2995

Table 8 *Deviations of coverage for the negative ring and ring-like SE prints for a 30 lpi/900 dpi*

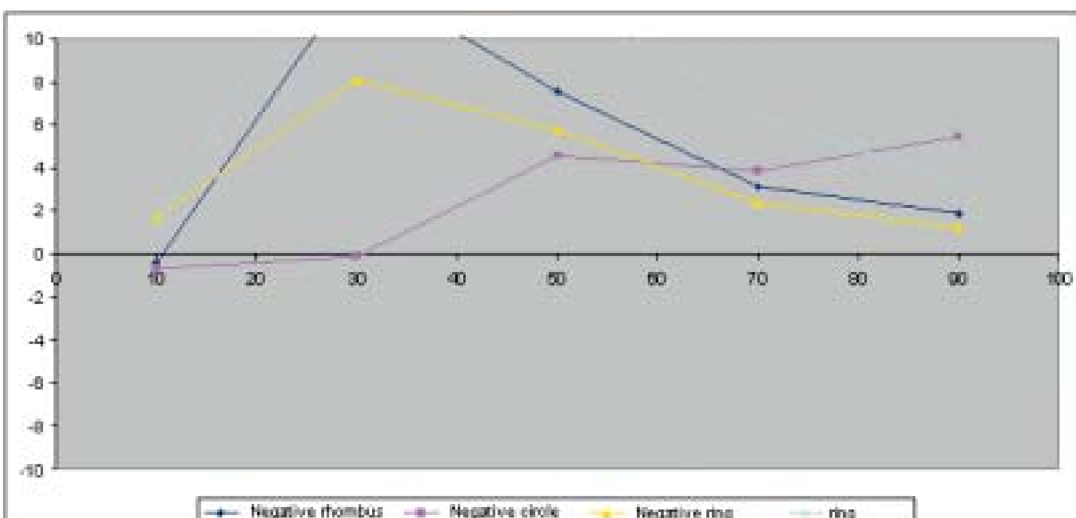


Figure 40 *Deviations of coverage with printer prints for a 30lpi screen ruling*

3.4 Deviations in digital printing for mutants

All mutants have double outlines in some values for given coverage, and this adds to insecurity in SE spreading after printing. The relative dot gain is low in low screen rulings and this is evident in coverage measuring. Comparison is given through graphs in Figures 39 and 41 for 5 lpi and 30 lpi. Deviations for 5 lpi are neglectable, except for coverage of 50% for M65 and 30% for M66. Multiple testing and scanning has been carried out and the report says that there are the same deviation occurrences but in different coverage areas. The tables 9 i 10 give marks for the scanned print images (m1z5, m2z5, m3z5 and m4z5) for which the enclosed results are shown.

coverage % **Printer 5lpi/900dpi**	coverage % M65, m1z5	deviation	coverage % M66, m2z5	deviation
10	10,3607	0,3607	10,6843	0,6843
30	29,9581	-0,0419	27,7334	-2,2666
50	47,8677	-2,1323	48,8203	-1,1797
70	68,1292	-1,8708	69,4881	-0,5119
90	89,5086	-0,4914	89,9847	-0,0153

Table 9 *Deviations of coverage for for mutants M65 and M66 prints for a 5 lpi/900 dpi*

coverage % **Printer 5lpi/900dpi**	coverage % M67, m3z5	deviation	coverage % M68, m4z5	deviation
10	10,6635	0,6635	11,3407	1,3407
30	29,4778	-0,5222	31,9917	1,9917
50	48,0531	-1,9469	49,4890	-0,5110
70	69,1062	-0,8938	69,2674	-0,7326
90	89,9380	-0,0620	89,0219	-0,9781

Table 10 *Deviations of coverage for for mutants M67 and M68 prints for a 5 lpi/900 dpi*

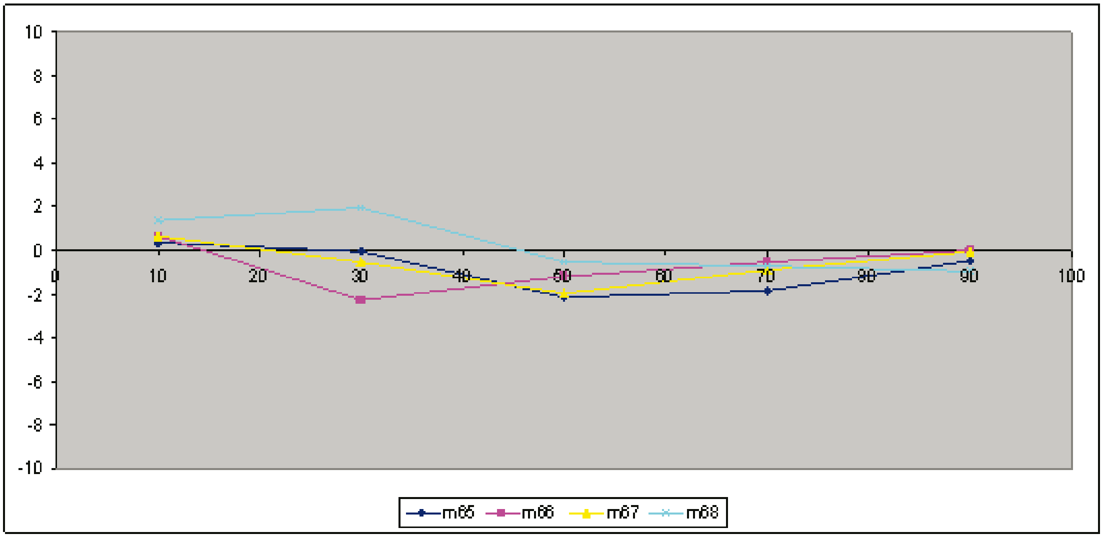


Figure 41 *Deviations of coverage of mutants M65, M66, M67 and M68 for a 5 lpi*

Figure 42 shows the SE for mutant M68 for 5 lpi. Dot gain is relatively small for 50% coverage as well. For coverage with a 30 lpi liniature the relative dot gain (RE value / whiteness) is significantly higher, so that even at 70% of coverage there is linking of SE parts that should be only black (as is defined on the RIP SE level).

Figure 42 *The Mutant M68 environment at 70% coverage for print 5 lpi / 900 tpi*

The 30 lpi screen ruling has deviations in coverage to an average 4.2%. The lightness have not been altered for the scanned images, although it is generally the first step in adjusting coverage for an overall digital record before printed forms are made. Therefore all the print coverage is greater than the given ones. This is something that is easily corrected. The mean value for coverage deviation is set to zero. Thus the relative deviation remains and it can not be corrected for the whole image to be reproduced. By lowering the mean value by 4.2% for M67 (the yellow line on the Figure 43), the maximum deviation would amount to 4.1% (at 30% coverage) and the negative deviation value would be -1.9% (at 70% coverage).

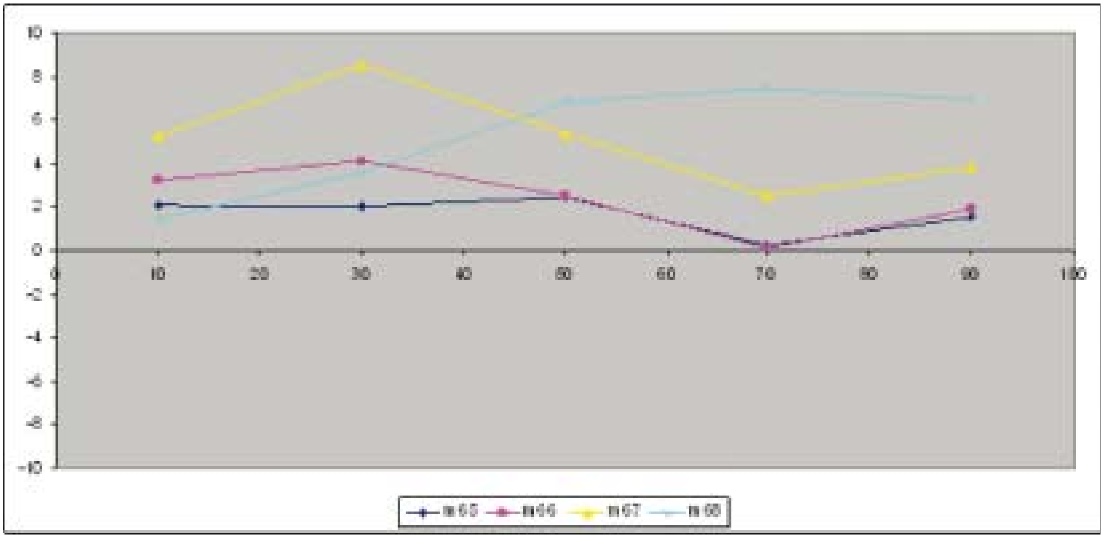


Figure 43 *Deviations of coverage of mutants M65, M66, M67 and M68 for a 30 lpi*

3.5 Analyzing the screen element environment dot gain structure

Dot gain is very much present in print in each individualized SE. The SE environment becomes less sharp, and this alters the print's sharpness parameters (Figure 44). The first aspect is the image becoming dark and a certain hazy cloud appearing. SE altering may be present when carrying out the printed form, in each step of the graphic reproduction separately. This is also the source in compensation programming; by SE reducing or enlarging before printing.results are shown.

Dot gain depends on print type, paper type, and screen frequency type – screen ruling, manner of RIPing, film execution resolution or CTP plate. An adequate image interpretation can be improved if the printing conditions are known. If PostScript is formed for unknown printing conditions, it is necessary to activate transfer functions. Their preparing is a very extensive function and parameter matrix where there is description of numerous cases with different printing techniques.

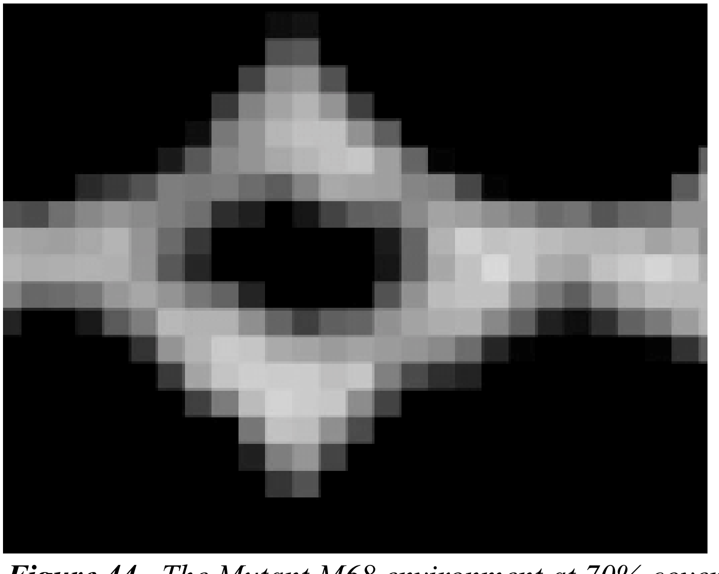


Figure 44 *The Mutant M68 environment at 70% coverage for print 30 lpi / 900 dpi*

3.6 The coverage structure of mutant M68 for Xeikon printing

Digital electrography is increasing as to its application. Graphic design uses digital printing for presenting ideas on paper. Xeikon is an eight color printing machine with electrographic technology. Xeikon ink is not transparent.

The print environment is shown in the form of ratio: total SE blackness, total whiteness, and in-between-area named gray. This gray area is divided in the graphic representation into highlights in two parts: the smaller 50% (blue) and highlight greater than 50% (red). Coverage is given (integrated dot gain) that takes into account the participation in the dot gain intensity of each gray scanned pixel separately when making the calculation. 'Colored surface' is only the summation of scanned gray or black pixels. The colored surface is always less than the coverage, for all printing techniques. This difference becomes a subject for discussion on dot gain. This difference is not present in the digital record analysis after RIPing and before producing any kind of physical printed form type (film CTP) or print.

The new mutant SE named M68 (Fig. 44) has deviations in coverage at a level of 1% for 5 lpi. This can be simply «calibrated» in application. Adjusting at this level of preciseness may be carried out in defining coverage before screening, and it is possible to act also during printing. The overall colored surface is larger than the measured coverage. The area with totally black SE parts also falls into this surface, as well as the gray environment SE. The red area is the one that has dot gain higher than half of the ink coating value. The blue (upper) area represents lighter shades with dot gain lower than half the full color tone in SE. Spreading of this gray area marked in the graph as red and blue is gradual. Although the outline changing from screen M68 (Fig. 45) is not in constant

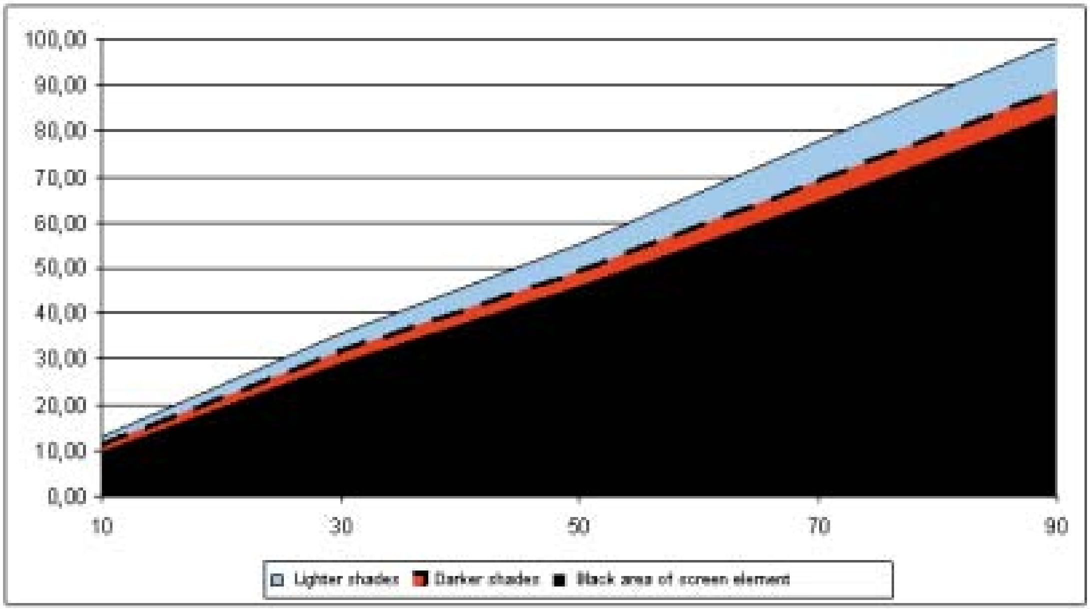


Figure 45 *Coverage and colored surface of mutant M68 / 5lpi*

change along with the enlarging of the defined coverage, the gray is constantly growing.

The print surface was scanned at a 900 dpi resolution. Pixels were obtained allowing coverage analysis and border dot gain for individual SE. On the SE borders dot gain of certain pixels declines towards the white environment. Ink spreading is present in almost all printing techniques. Each gray pixel contributes to the coverage with its relative dot gain. In higher screen rulings the SE becomes smaller but there is constant decreasing of the gray area. That is the reason why the gray pixel area spreads to the white area. This is accentuated in higher coverage. On M68 the white surface decreases for a 70% coverage and higher ones (at 30 lpi). The number of gray pixels grows for the same scrren ruling, whereas it decreases with the highest coverage values due to linking of neighboring SE.

The beauty of certain new SE is lost with screen ruling increase. The elements themselves become such as to be beyond recognition and we do not see them even when using magnifiers. Dot gain in certain gray pixels is exceptionally small and due to this it does not add to coverage. Coverage, being the basis in the scrrening task is satisfactory, and certain deviations may be adjusted for each printing technique. The thing that can not be accepted is image blurriness. One of the general conclusions is that the appearance of dot gain may be challenged satisfactory solutions can be found for all screen rulings in cases when it is considered on basis of coverage preciseness. If we are observing the image clearness, sharpness and appearance of certain accumulations called «cloud appearance» then the observations as to dot gain are completely different. This was one of the reasons why digital printing was being so slowly introduced into graphic practice. Dot gain structure for M68 at 10 lpi is presented in figure 46. Deviations of coverage at 10lpi is up to 2% in

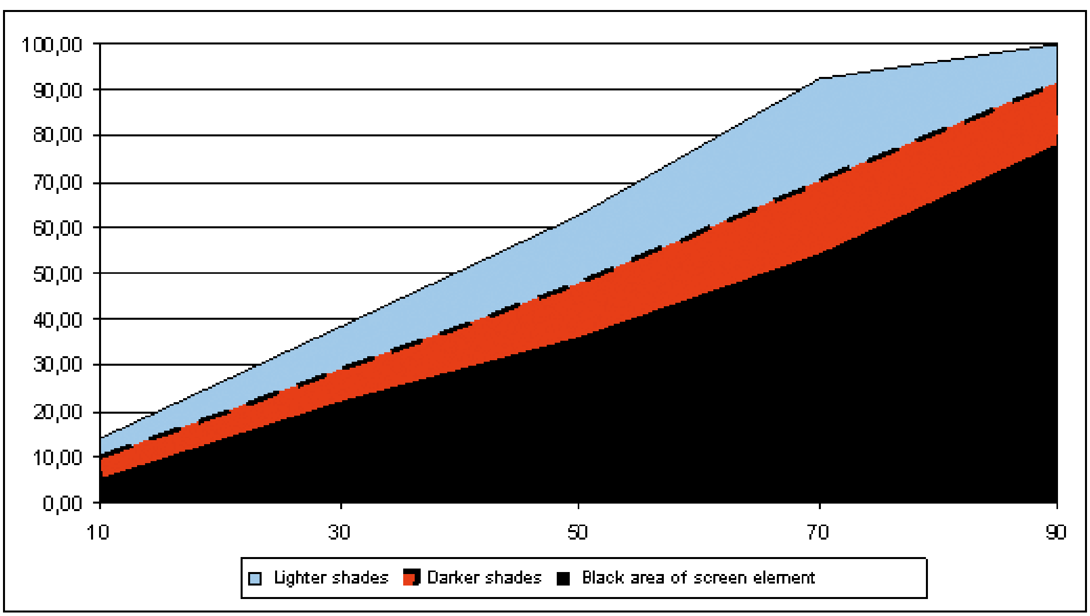


Figure 46 *Dot gain structure for M68 at 10 lpi*

its overall range. Corrections may be carried out as early as during graphic prepress if the procedure for coverage calculating is carried out.

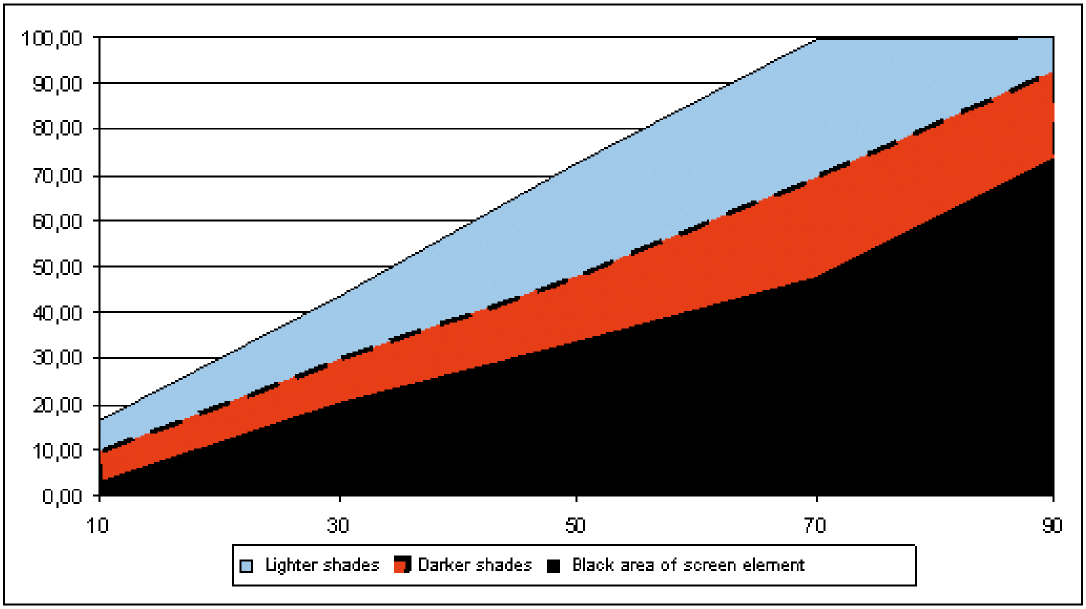


Figure 47 *Dot gain structure for M68 at 20 lpi*

It may be observed in the graph for 20 lpi (Fig. 47) that the white area declines as early as at 10 lpi screen ruling. When the screen rulings are higher, this effect is even more prominent. By screen ruling rise there is a relatively higher dot gain. The gray area closes when the coverage is higher than 70%, and the whiteness no longer exists as an element that improves contrast.

Conventional screen elements having only one outline also have a smaller effect of dot gain. This refers to measuring round dotted, square, linear, sinusoidal and their negative shapes . Dot gain for crystal and lace SE close the gray area for digital printing sooner than any mutant.

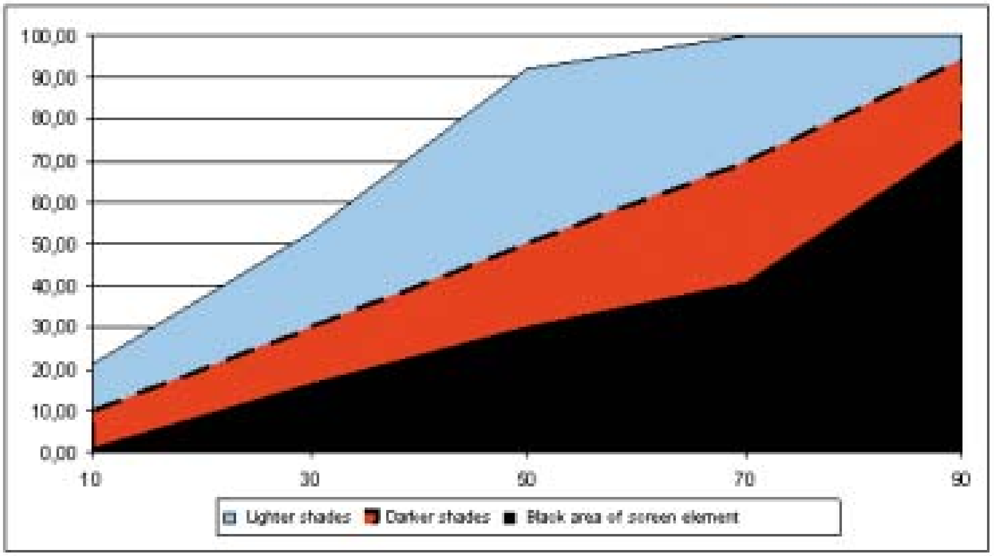


Figure 48 *Dot gain structure for M68 at 30 lpi*

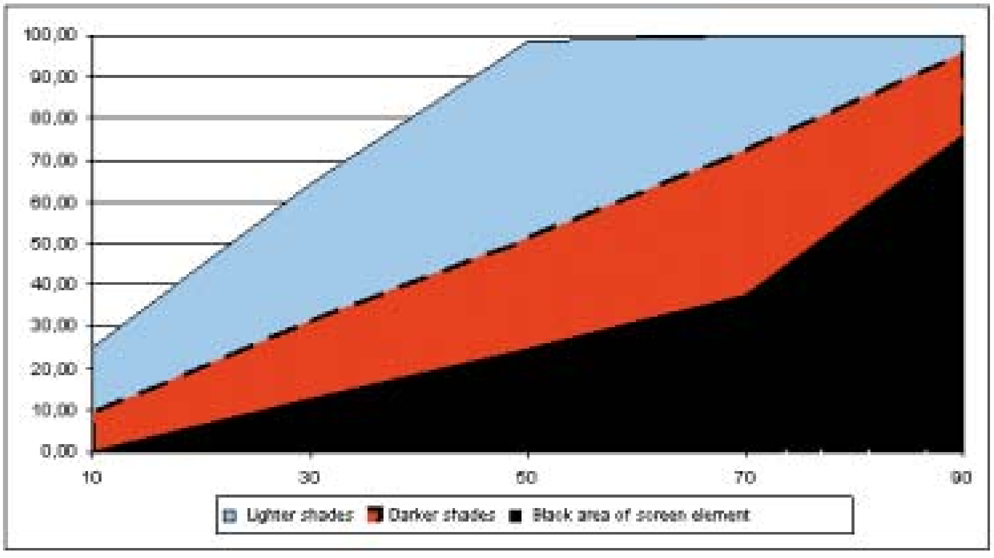


Figure 49 *Dot gain structure for M68 at 40 lpi*

As expected, the transition of 30 lpi (Figure 48) towards higher screen rulings (Figure 49) loses whiteness inside the screen cell. So there is closing of the white surface for 40 lpi as early as at 50% coverage. Digital toner printing builds the SE vertically to the printing surface, by applying toner to the same spot, so that toner appliance can not be controlled in a precise way. Any form of SE design is lost. Mutant SE should not be used in digital printing at such high screen rulings.

4. Experiments with variations of screen ruling, angle and screen element shapes

One example of stochastic variation of screen ruling definition are shown in Figure 50 with mutant M65. The range of random choice of screen ruling is from 20 lpi to 80 lpi. Color reproduction has been researched with the help of setting fixed angles: 0^0 for yellow, 21^0 cyan, 45^0 black and 68^0 magenta. Each color was allotted with a different initiator seed for starting a pseudo-random sequence. Generating of a random sequence is done with a congruent generator.

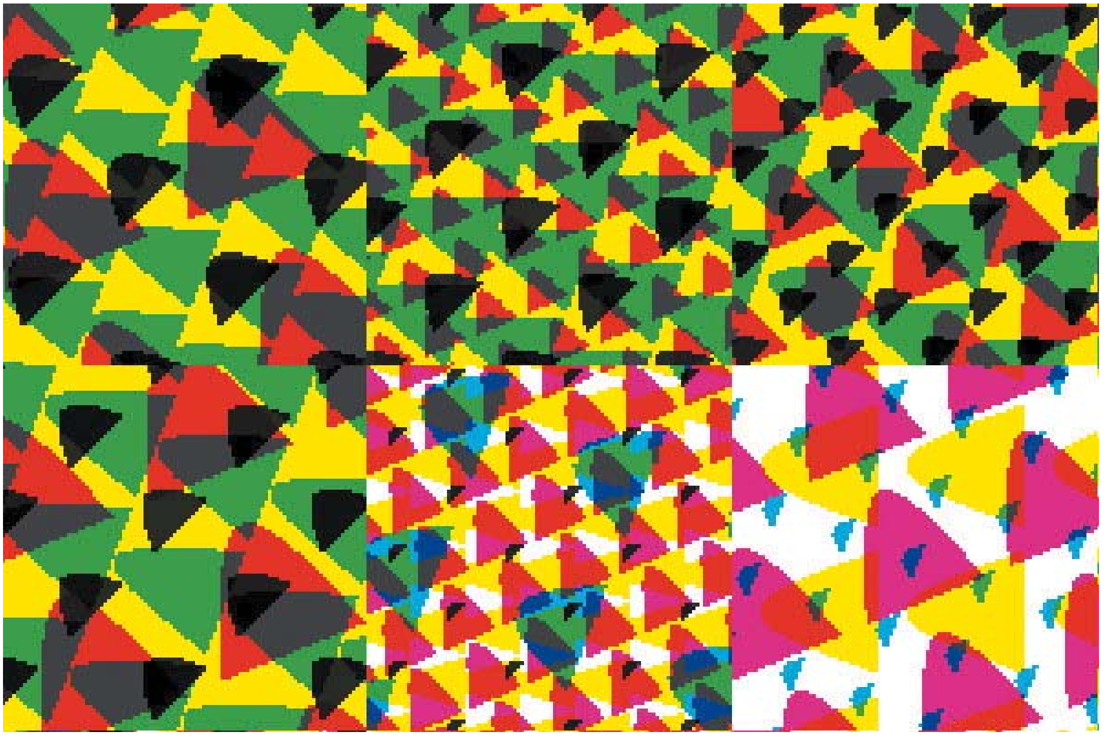


Figure 50 *The central 6 pixels of the picture "Flower" in stochastic screen ruling for SE M65 before printing (absence of dot gain)*

Great magnification in the flower border area illustrates composition of a screen M65 shape in all four colors (Fig. 51). Mutant, new screen elements with stochastic screen ruling and angle provide a good quality image interpretation without appearance of the moiré effect.

Figure 51 *Picture of flower with marked 6 pixels of Figure 99*

The micro structure of screening for several neighboring pixels shows possible individualization of the image's interpretation. Comparison with the prints made on ink-jet printers shows that there is difference (Fig. 52).

Each digital printing system adds its specific quality in building the color coating. This is exceptionally well observed in higher screen ruling where its own building of the screen element takes place over the one that is set through new SE. Good compositioning would be obtaine only when a high resolution of the digital printer is obtained. In printing with the CTP system there are no problems in reaching good-quality interpretations of new SE because their resolutions are even more than 3000 dpi.

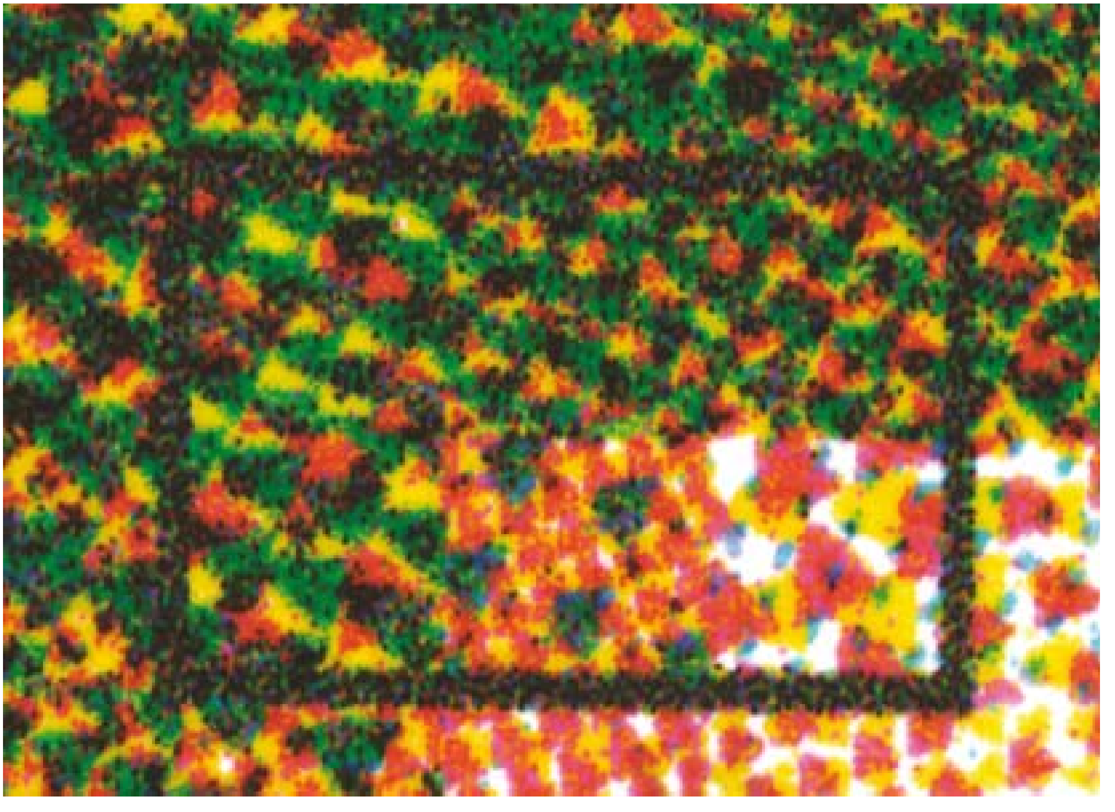


Figure 52 *Enlarged SE M65 pixels after ink-jet printing*

A portrait on figure 103 is solved with 4 halftone screen models (Figure 53). Pixel is enlarged, the number of pixels reduced, and screen ruling also reduced because of better presentation. Four solutions are compared. Standard halftone screen with circle dots and bigger screen ruling (150 dpi) is used as a control pattern (Figure 54a). Total control of the right way or working different screens, that are repeated one after another gives "shaped moiré" with a period of multiplication product in the size of a pixel in the number of different screen models in program (Figure 54b). Moiré disappears if a selection of screen model is done randomly. Except this, screen ruling can also be randomly picked (Figure 54c), as well as the screen ruling together with screen rotation angle (Figure 54d).

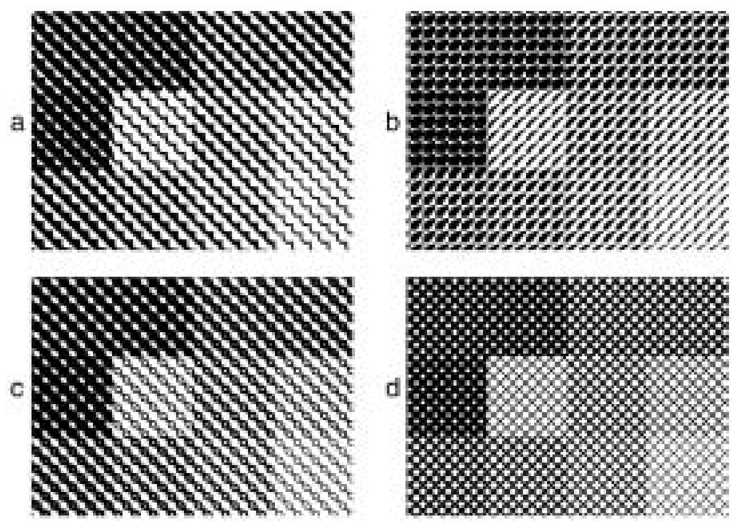


Figure 53 *4 halftone screen models for random selection*

Program solution becomes denuded, but it is created in a way which can make each researcher interested in it, continue the development of his own algorithms, procedures and finally apply it in specialised usages .

Fig. 54 *a) standard dot halftone screen*
b) screening with cyclic continuity of screening algorithm
c) screening with stohastic selection of halftone screen element shape algorithm (SEED = 12345678) i a *= 0˚*
d) screening with random selection of halftone screen element algorithm and random selection of screening angle a *(SEED = 246135)*

5. Color transparency in covering with various screen elements

By rough image screening with especially designed raster elements, the screen element becomes the carrier of the communication message. The whole image may be shown as screened in small screen ruling or may be screened only partly to be intriguing. Images are created with special screen element shapes the goal of which is to show some innovation in graphic designs. Designers compete in making their designs; they publish their work in graphics magazines. We must point out to the fact that the listed published designs have already been carried out with already seen screen forms. Stochastic compositioning is not present because it demands a complex algorithm and the same time the presence of several new screen elements in the same reproduction.

In this chapter the high security degree of the image extends to real image application into which information has been integrated from some other, completely different image. Only the first image is screened, i.e. the gray level of certain pixels determines its coverage in each individual pixel. The second image called "sample" is for choosing the parameters of screen shape, screen ruling and screening angle. This is why two independent random digit generators have been set. The first generator takes care of the basic picture and the second generator on the sample information. If the pixel gray level values in the sample are more than half of the possible gray level, then screen elements are chosen with the help of an algorithm from the second generator. The image examples (Fig. 55) are a portrait and sample in the form of letter MM images.

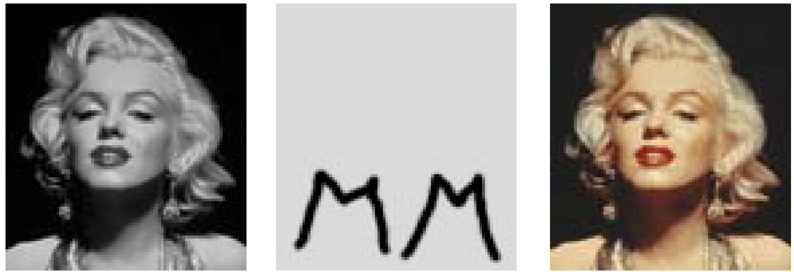


Figure 55 *Two pictures; a portrait and MM initials signature*

The idea to link information from two images has been carried out with the help of independent stochastic screen ruling, angle and screen type determining for each image separately (Fig. 56, 57, 58, 59, 60).

Figure 56 *Fixed screen ruling of 10 lpi and angle in the position of letters MM. Letters MM (sample) are screened with r11 (negative rhombus)*

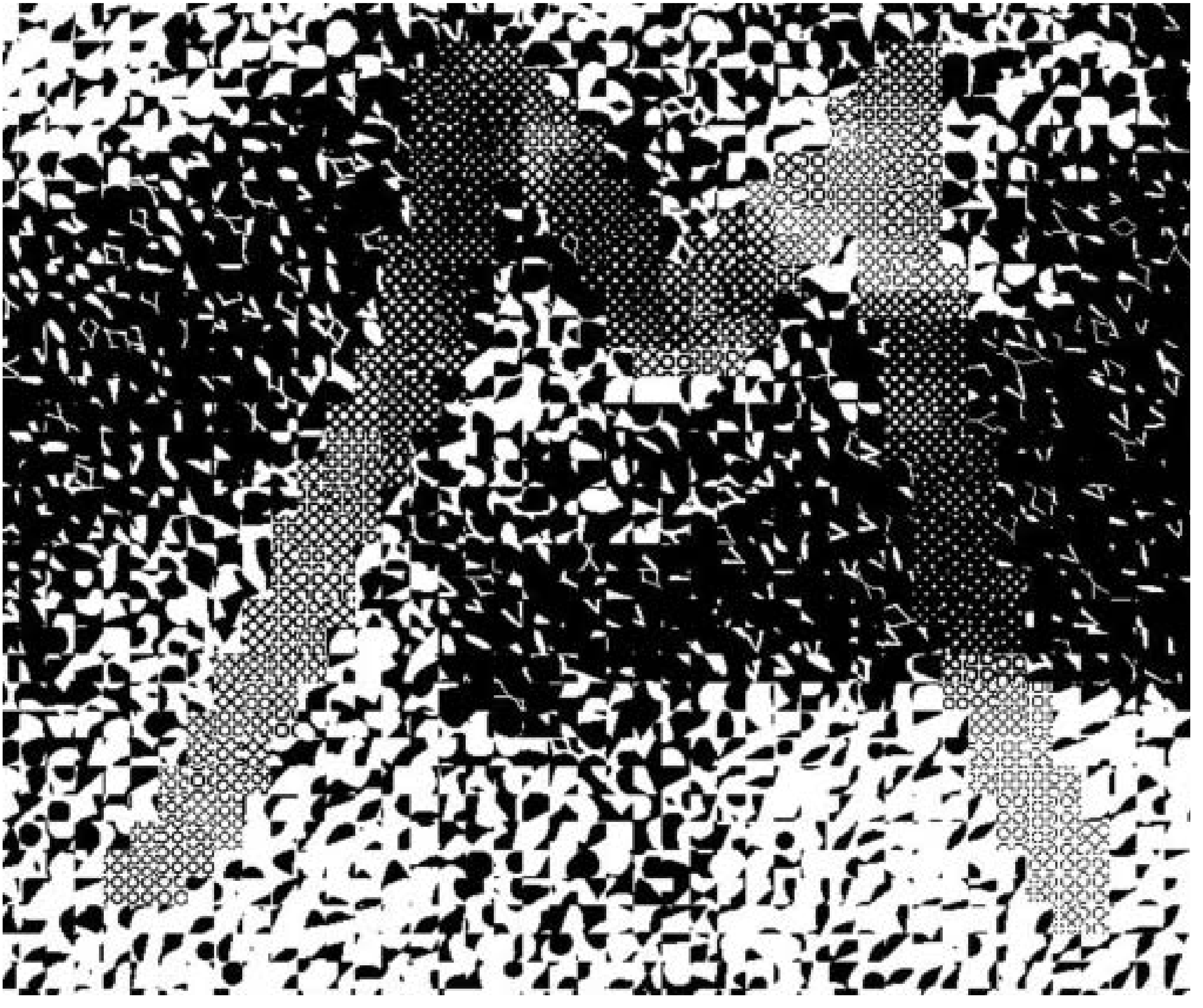


Figure 57 *Ring screen shape in the position of letters MM.*
Image screen elements are mutants M65, M66, M67 and M68


Figure 58 *Black and cyan, screen ruling 10 lpi to 30 lpi*


Figure 59 *Magenta and yellow, screen ruling 10 lpi to 30 lpi*

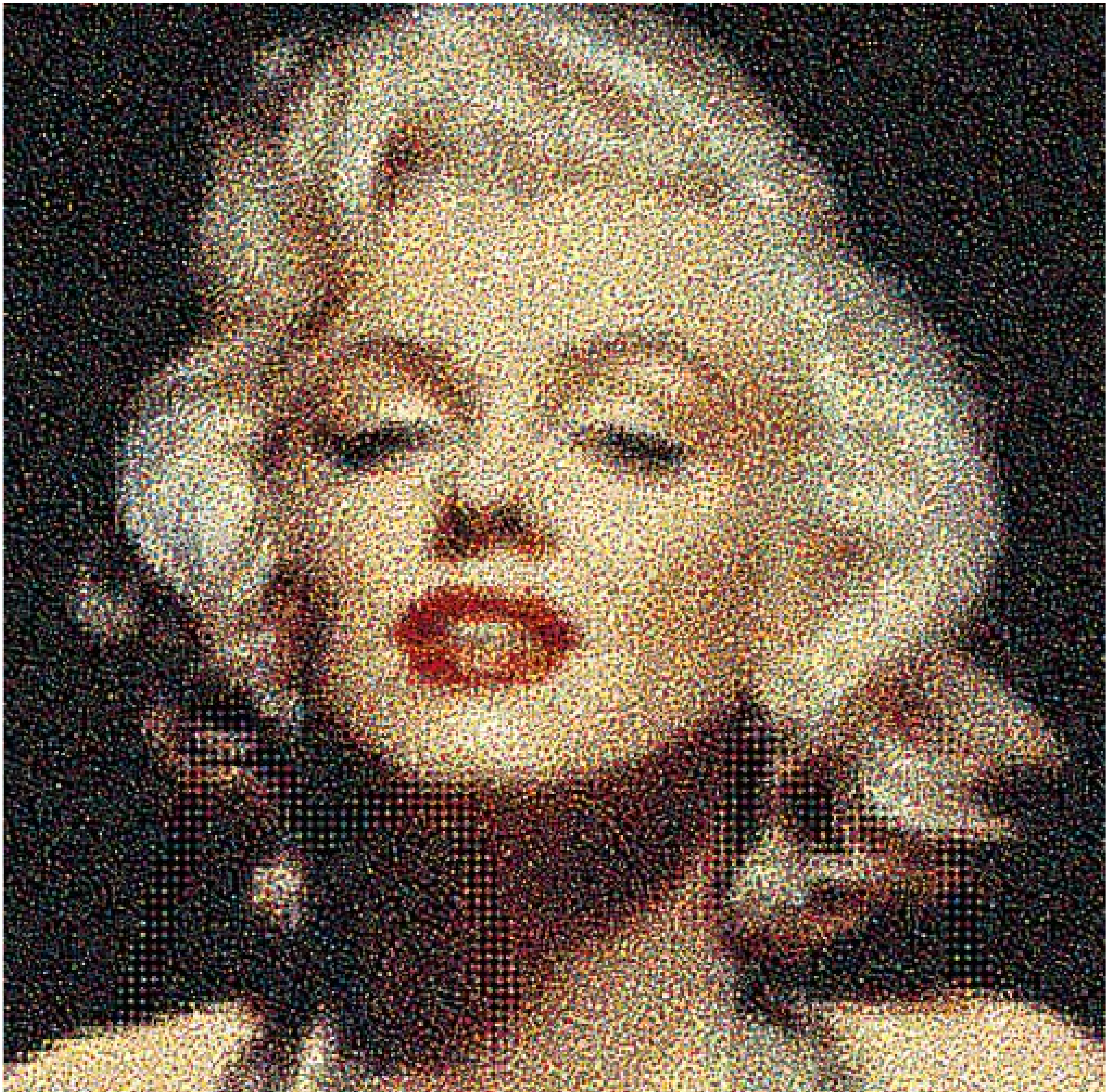


Figure 60 *Color picture structure with MM logo in the black channel and SE r11 in the sample*

In a security program or copyrighted design it is recommended to have opposite screen ruling, SE type and screening angle setting. The solution for the MM example has a constant screen ruling in the initials area and only one SE shape, and this is in contrast with the design for the rest of the picture. The portrait is designed with a stochastic screen ruling that is in average twice the size of the initials area. Only such different surface designing achieves the quality of the MM initials to be recognized (Figure 61).

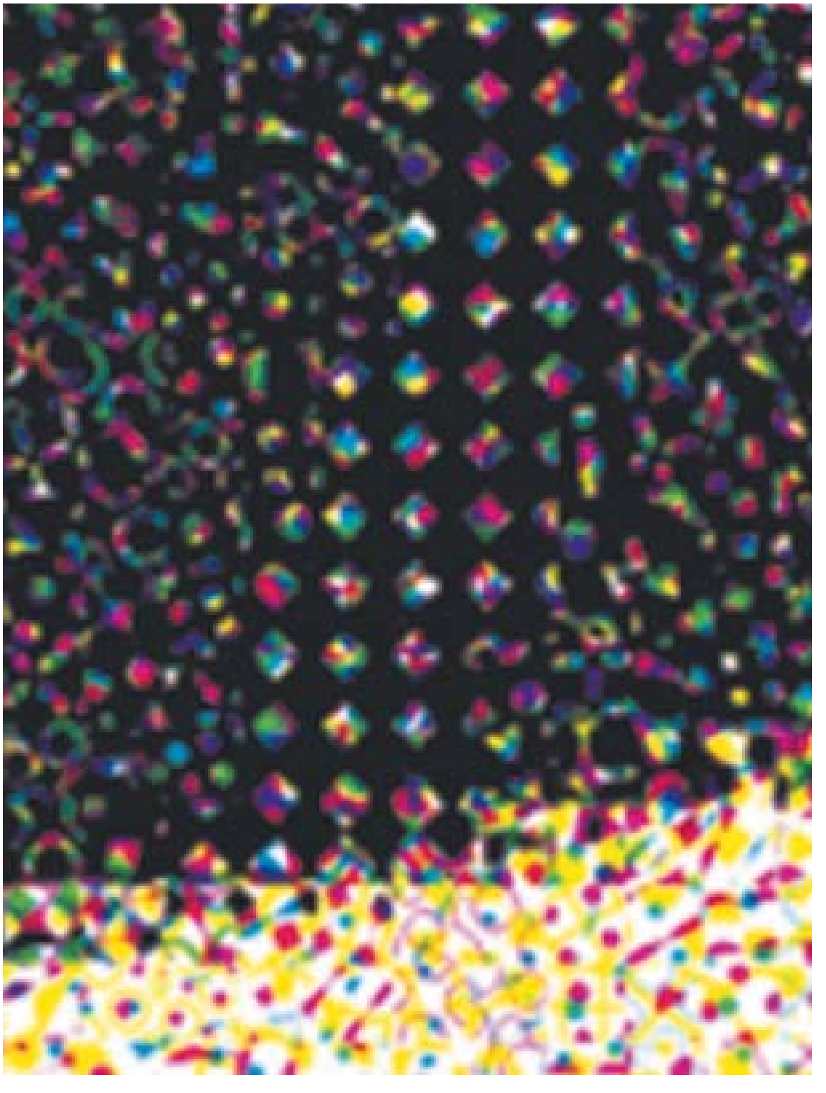


Figure 61 *Enlarging of part of MM letters in CMYK display and r11 in the black channel*

In Figure 62 "Ivana" stochastics are applied in several parameters determining the pixel design. The pixel deformation is strongly stressed. A horizontal and vertical move away from the basic geometry has been added to the pixel. The pixel initial point shift is also present. Certain colors do not fall onto each other in the same place. Each color has individualized positioning for each pixel separately. The picture has been designed in three colors: cyan, magenta and yellow. Low screen ruling is joined to magenta and the yellow color. Cyan fills in the higher screen ruling pixel so that borders with prominent deformation can be observed for this color.

The strictly planned design with centralized graphics inside pixels demonstrates modern design strength (Figure 63 - "Roko"). The pixel center is designed with magenta and circle form of the screen dot (SE). The pixel borders are designed with «empty, central screen element». Those borders are filled in with cyan. A mesh structure is joined with yellow color. It has been made as a «hollow» screen from square structure. It gives the impression of lines that are vertical to each other. The black color has been carried out as concentrated thin lines (three in a pixel). Pixels that have coverage in the K channel amounting to less than 10% show a dot structure in a circle layout. All SE have 10% deformation, so the circle elements are of elliptical form, whereas the mesh structure is yellow and has a small flattened part.

In figure 64 "Grga" pixel geometry deformation is applied to each pixel. The stochastic value is introduced into the PostScript command where the parallelogram form is defined for carrying out the pixel. The pixel has lost its initial form and is deformed and moved from its basic bed. Loss of square form may be dependent on the exterior algorithm that is linked with the piece of information in the base of the images individual determining. The pseudo-random procedure provides the possibility to repeat graphics (efficiency in proving the originality) and the special quality of the design through linking with information from the image base. Each color has been assigned with a separate screen form set, a separate screen ruling and an angle for screen element proceeding inside each pixel separately. Figure 65 and Figure 66 presented final exotic results for possible security usage.

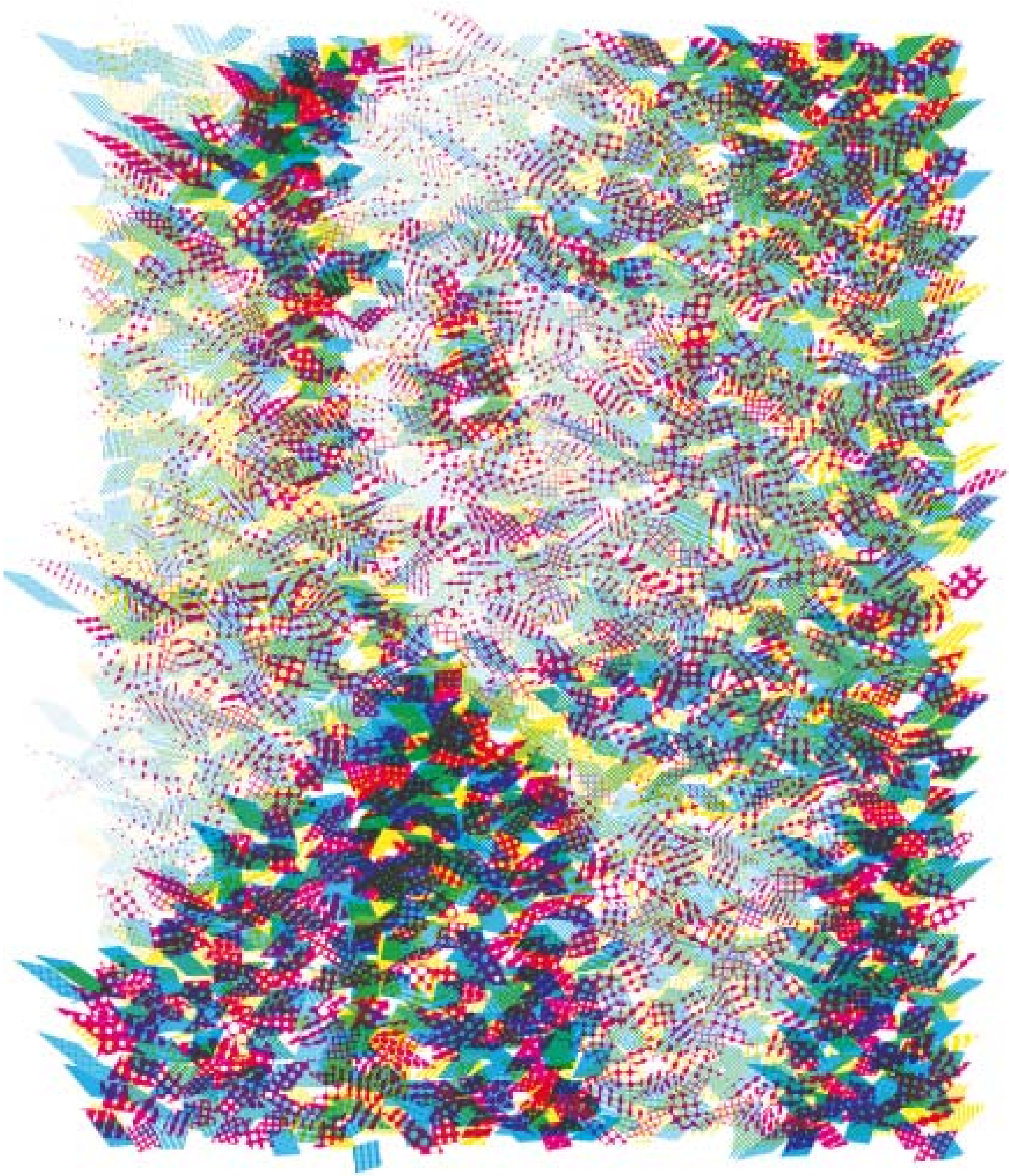


Figure 62 *Ivana*

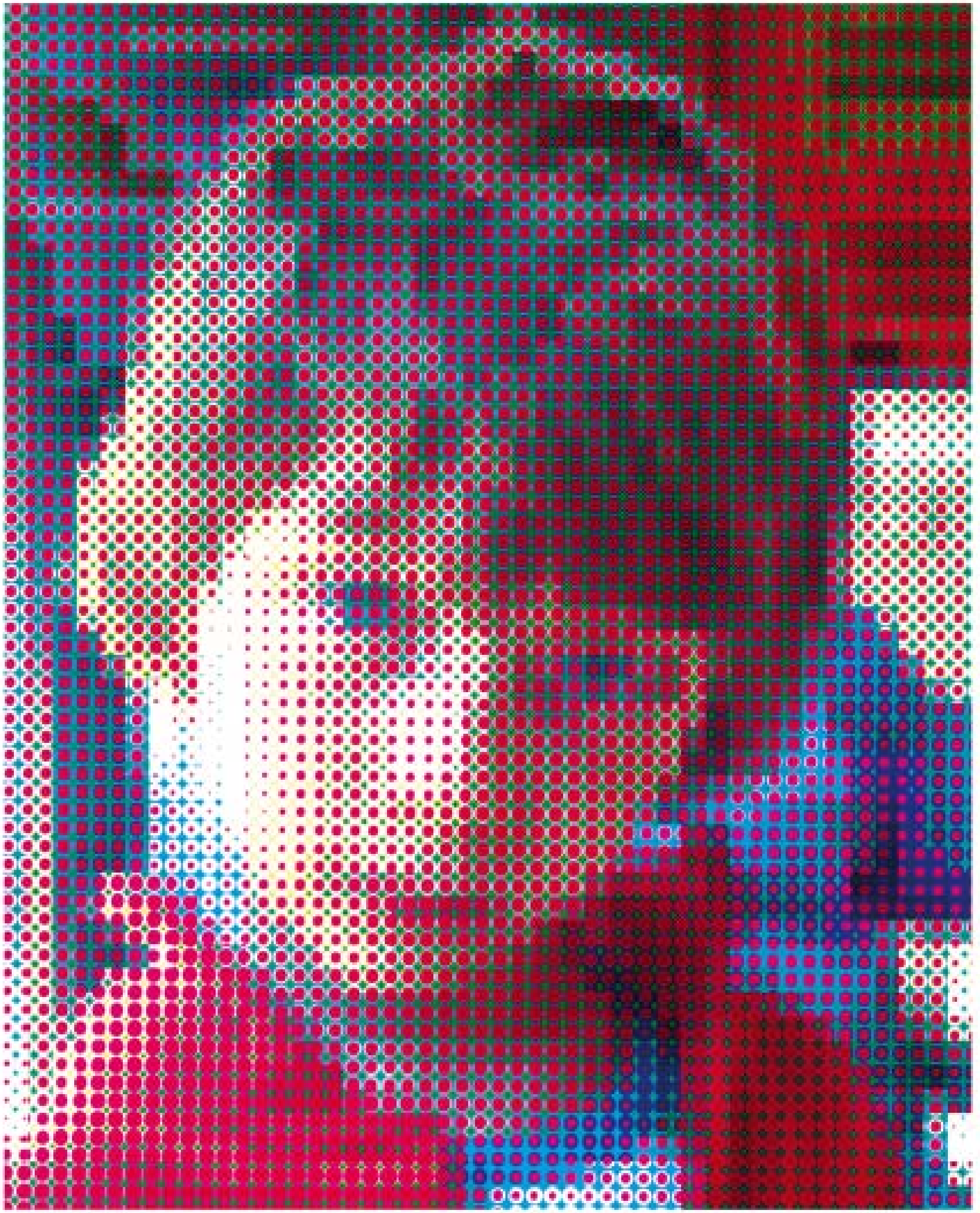


Figure 63 *Roko*

Figure 64 *Grga*

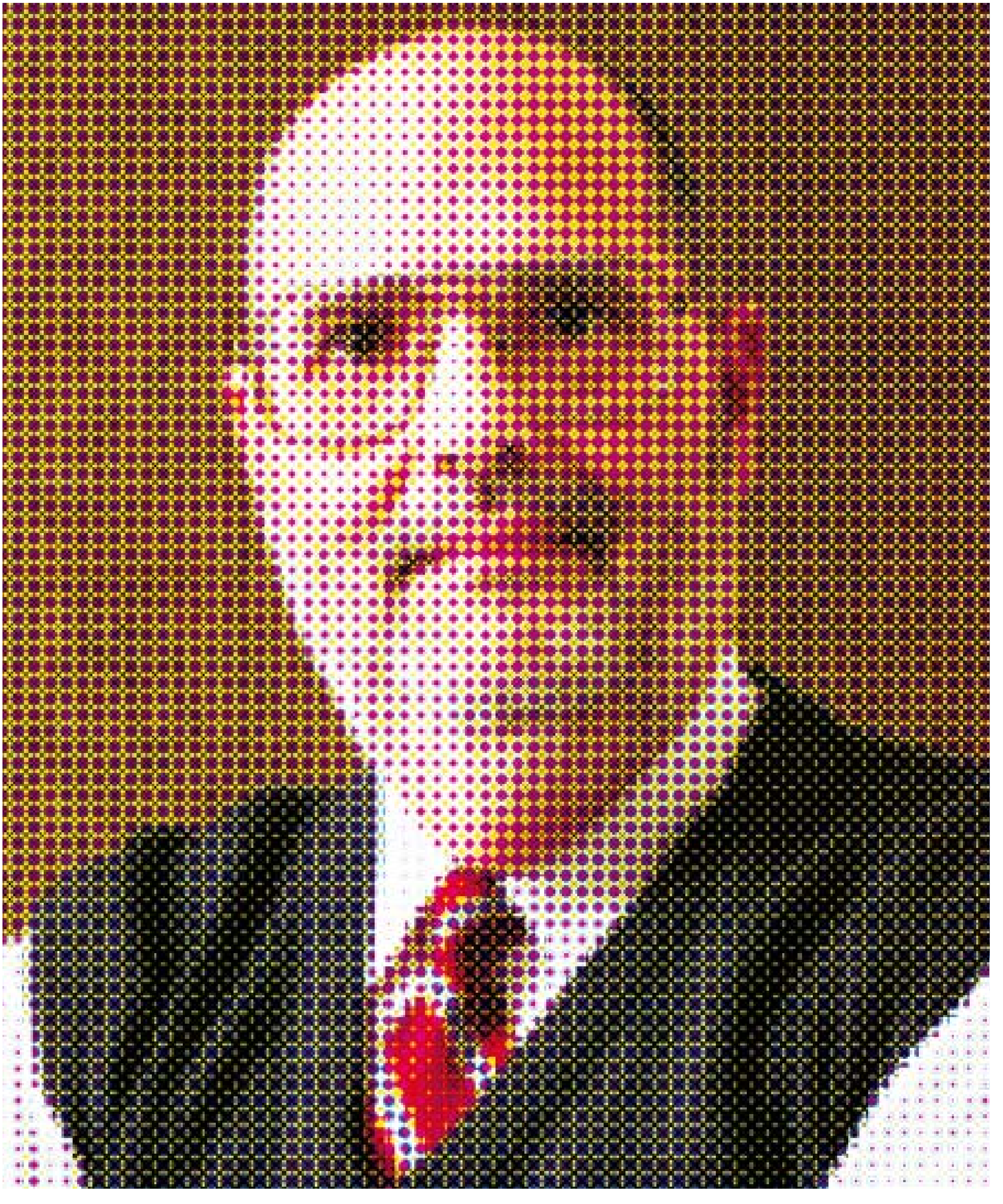


Figure 65 *Frank Romano*

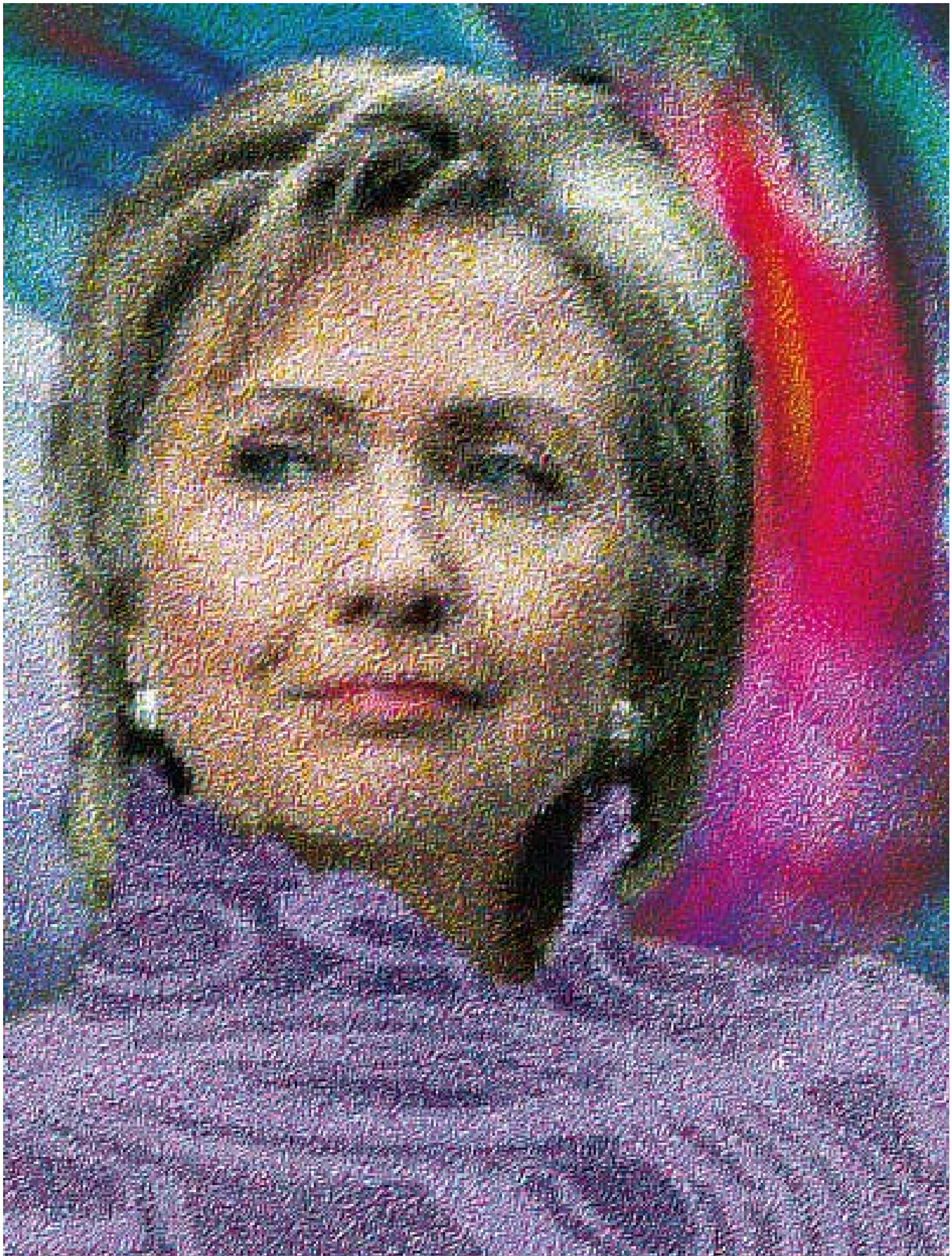


Figure 66 *Hillary*

6. Experimental frame for minimizing of screen ruling of new screen elements

In general application conventional screening is based on the use of only one screen element. Usually there is word about wishing to achieve top quality in interpreting the original. Daily newspapers and reviews are ideal media for promoting new graphic techniques. It is almost daily that these screens appear in the most various designs published in high printing runs (Vecernji list, Vjesnik from November 2006). On basis of agreement with the publishers, screening of screen design examples have been carried out in such experiments as everything had to be printed in one color only or in the CMYK color system. Prints in daily newspapers with the largest printing run in Croatia (Vecernji list), are proof that it is possible to design and use new screening methods. Such screening need to be prepared as bitmap structures for each color component separately. Nobody from the newspaper production area has been informed about these experiments that have been carried out with new screen elements and procedures. Tests are continuing, each week with new screen designs.

Individualization

A work of art – the painting entitled 'Mask' (mask) from the book 'Masks' has been used for interpreting software designs in the individualization area. The head of the central figure in the painting was taken. The painting has color contrasts. All the colors are present in strong rhythm. The test with yellow and black channel interaction is exceptionally illustrative in the painting segment. The printout of the channels for certain colors is smaller, and in this sense the enhanced screen ruling is inversely proportionate. Channels: magenta, cyan and yellow have been designed without any relation to sample values of some existing record. A 5 lpi to 25 lpi screen ruling has been given for all those channels, with random chosen values according to the congruent method with generator seed.

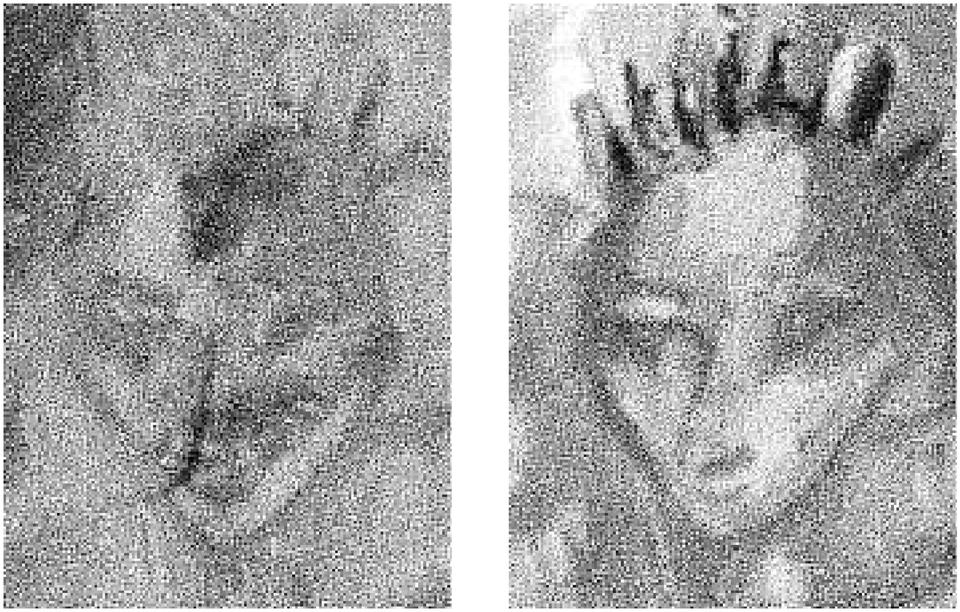


Figure 67 *'Mask', magenta and cyan channels*

Figure 68 *'Maska', yellow and black channels, ring screen shape in low gray levels in yellow color*

Special attention has been paid to find a solution for the black channel. It is linked with the information for the yellow color channel. In places where the yellow color tone is less than half of the gray level value, black color is presented with a stochastic layout. In places where the yellow color coverage is greater than 50%, the black color is screened with fixed values of screen ruling and angle screen parameters.

It is stressed that the image is screened in all the area with values from the black channel. Only the screen element choice is controlled by gray level from the yellow channel. As periodicity has only one channel (black, in some places only), there is no moire effect in the overall picture with all the colors.

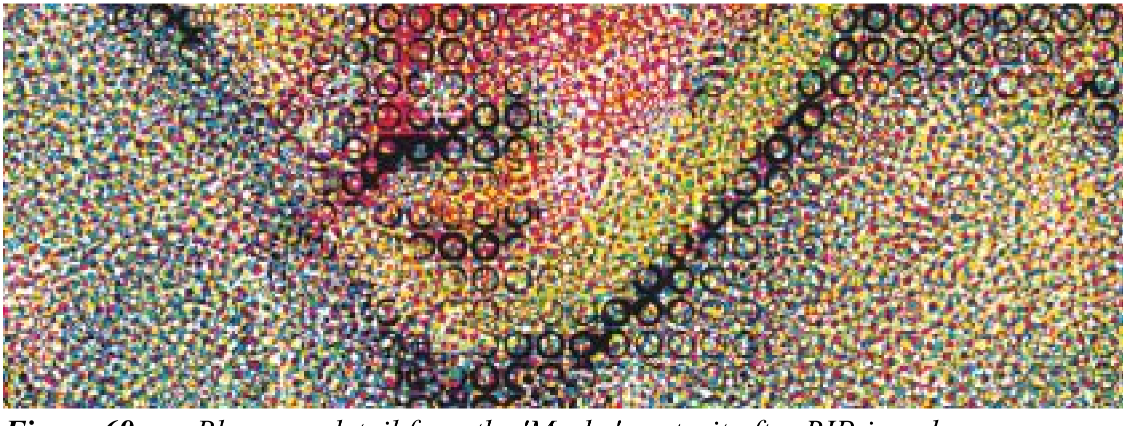


Figure 69 *Blown up detail from the 'Maska' portrait after RIP-ing phase*

In this solution information of the yellow and black channels are linked on basis of the proposed logic. It is possible to use some very personal data from the portrait for the purpose of individualization. For instance, the threshold for yellow channel use could be the date of birth of the person whose portrait is being made.

The detail of the color screened color picture (Fig. 69) stresses the used intervention in the black channel. Low screen ruling is used on purpose in areas of intensive yellow color presence, and this shows the possibility of multiple controls in the screen element choice use. Although this screen ruling was used in one part only and of one channel only, the contrast may be observed and the intervention is recognized. The small screen ruling has added to the impression of something special and it makes the graphic work unique. Such interventions are not only interesting from the designer's point of view, but they secure to a great extent the reproduction originality. Without having all the data for generating procedure for choosing all the screening parameters, it is not possible to repeat individual reproductions. Thus each picture is screened in its own manner, it becomes an original, one of its kind, i.e. protected graphic work.

Application in security document printing requires the choice of brand new screen elements, unpublished to date. Such an approach leads towards security graphics on the level of screen element choice. In the black color channel spots where gray level is greater than half of the value, a ring type screen element was used.

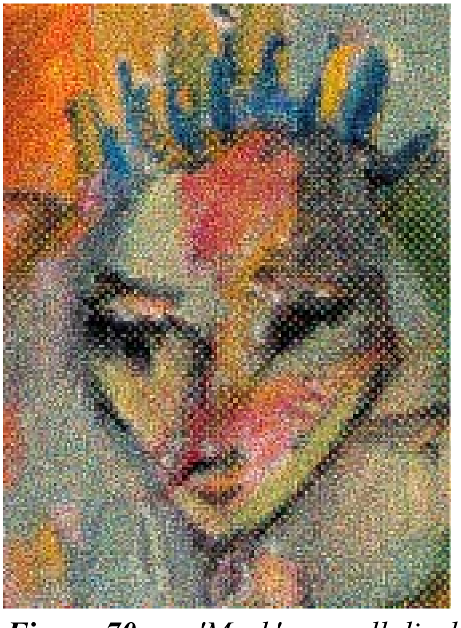


Figure 70 *'Mask', overall display in CMYK (RIP)*

This picture (Fig. 70) was carried out on several different materials: coated papers, metal-coated papers, highly absorbent papers. Small screen rulings kept their form, while the remaining, randomly chosen shapes underwent deformation. The transition of the ring-shape screen is prominent at the place of transition of two pixels with different coverage values (Fig.71).

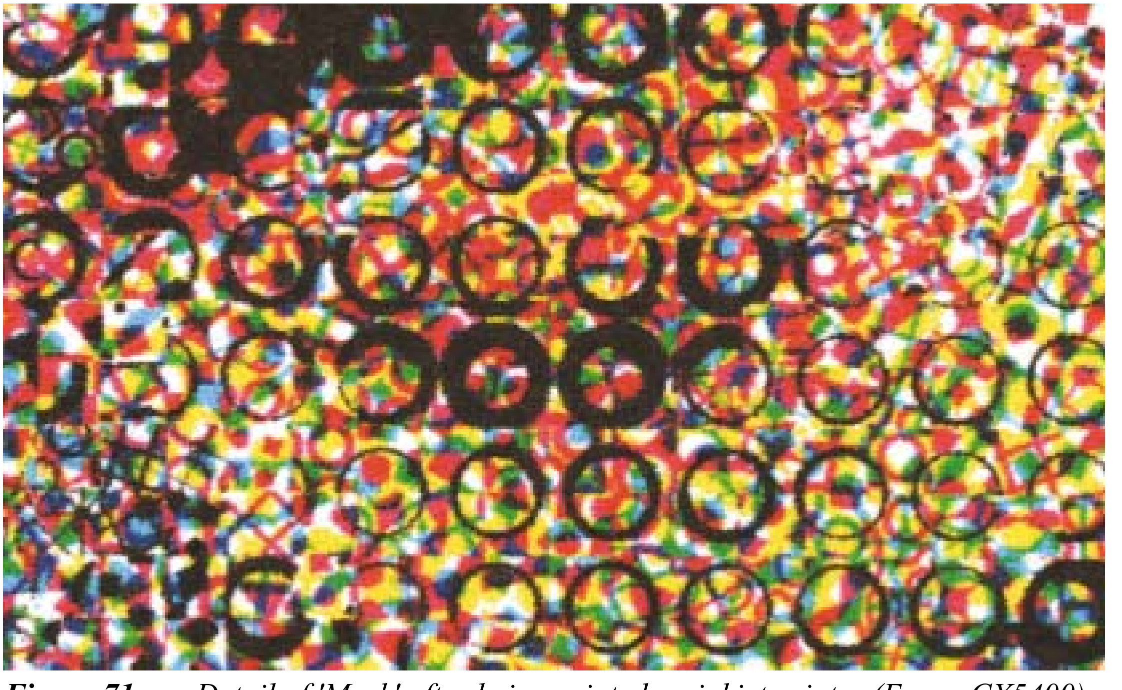


Figure 71 *Detail of 'Mask' after being printed on inkjet printer (Epson CX5400)*

7. Screen Element Shape Mutation with Growth Function Parameterization

New halftone screening shapes have been created that alter their basic shape as their parameter alters. Due to this transformation of shape we have named them mutants. These shapes have a high dot gain in printing, so they are not to be recommended for high screen ruling. Therefore we recommend them for the area visible to the human eye. Such screen systems are applied in jumbo posters and in graphic work with exceptionally strong messages. Due to the fact that these designs are subject to pseudo-random generating where the initiator is known (congruent method seed), they are ideal for individualizing neutral surfaces in documents. The security is based on secrecy of parameters in the congruent generator algorithm and in parameters with which the screen shape is distorted.

It has been established during research work on mutating screen element limitations with parameters that are found within the screen element mathematical definition that there is no general rule for free screening element altering. Mathematical modeling helps in setting the boundaries for permissible screen element shape shifting, although errors may occur here as well. The blow to the screening cell border can be set correctly only on basis of testing programs for carrying out graphic samples' screening.

7.1. Mutant Screen element and its definition

The complex modified screen mutant R73 is given in the following mathematic relation and program code:

$$1 - \mathrm{Abs}\left[x\,y + \mathrm{Abs}[x] - \mathrm{Sin}\left[\sqrt{x^4 + 4\,y^4}\right]\right]$$

```
1- Abs[Kory*y*x + Abs[x] - Sin[Sqrt[(x^4+4*y^4)]]]
```

This is the screen element growth function with the help of which the screening cell is built in the screening process for a set gray level and screen ruling. The *kory* correction parameter has been incorporated into the mathematical formula program sequence with the help of which experiments are made as to generating the initial form mutating sequence.

Model 2D (Fig 72) shows the appearance of the screen element for 16 discrete gray levels for one and the same growth function. If the halftone screen that we are developing rapidly changes its form through the grayscale, we can increase the number of discrete gray levels in this 2D simulation model in the course of experimenting. Changing of the shape throughout the grayscale should not be mixed up with halftone screen altering due to our mutation parameter. These are completely different issues.

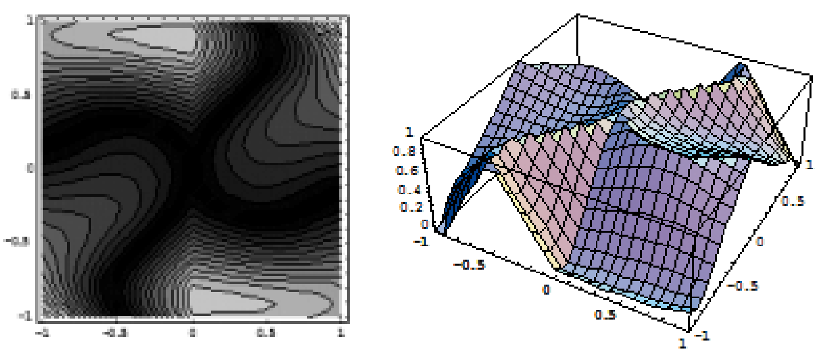


Figure 72 *The 2D and3D model of screen mutant R73 with kory=1*

The 2D model is not sufficient for determining the allowed '*kory*' parameter values. This is the reason for using the 3D model (Fig 72) for screen element growth. With this model we can research much better the growth function boundary conditions. The allowed values for 'kory' parameter within the [0, 1] interval have been determined on basis of experimental research of shapes with the 2D model and boundary conditions control in the 3D model.

7.2. Paremeter of mutation

The *kory* parameter introduced here is included in the continuous function with values from 0 to 1 in the execution program. Figure 73 shows the mutant with the *kory* parameter that equals to =0.5, and Figure 74 shows the mutant with the *kory* parameter equalling to 0.

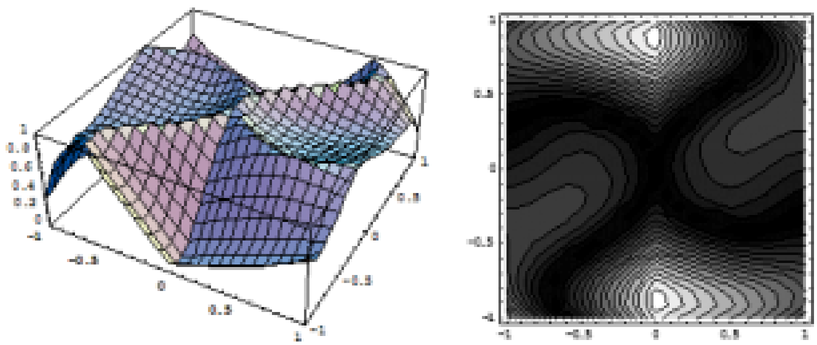


Figure 73 *The 3D and2D model of screen mutant R73 with kory=0.5*

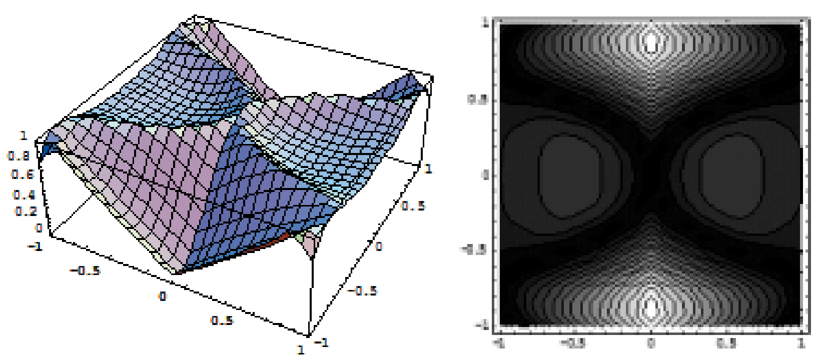


Figure 74 *The 3D and2D model of screen mutant R73 with kory=0*

The mutation parameter has been designed in such a way that by its application there is altering of the screen element shape from symmetric shape (*kory=0*) to asymmetric shape (*kory=1*). Thus the *kory* parameter is at the same time the shape deformation parameter for the screen shape so that the name mutant suits it even better.

7.3. Mutant screen in gray level and angle testing

The software solution has been made with functions that include the transformation model that can be generated either continuously or stochastically. The screen has been tested in detail in the definition area. Low screen ruling are analyzed by print scanning.

Figure 75 shows experiment results after testing mutant screen R73 for different gray levels and different angles. A rough screen ruling of 3lpi is used in all the examples in order to observe the parameter mutation development in the best possible way. Each row represents one mutant. The zero mutant is in the first row where the *kory* parameter amounted to 0, and in the last row the mutant was with kory=1. On basis of analyzing such experimental results under low screen ruling and various angles, decision is made as to the allowed initial and final mutation shapes, and even as to discrete mutations, if necessary.

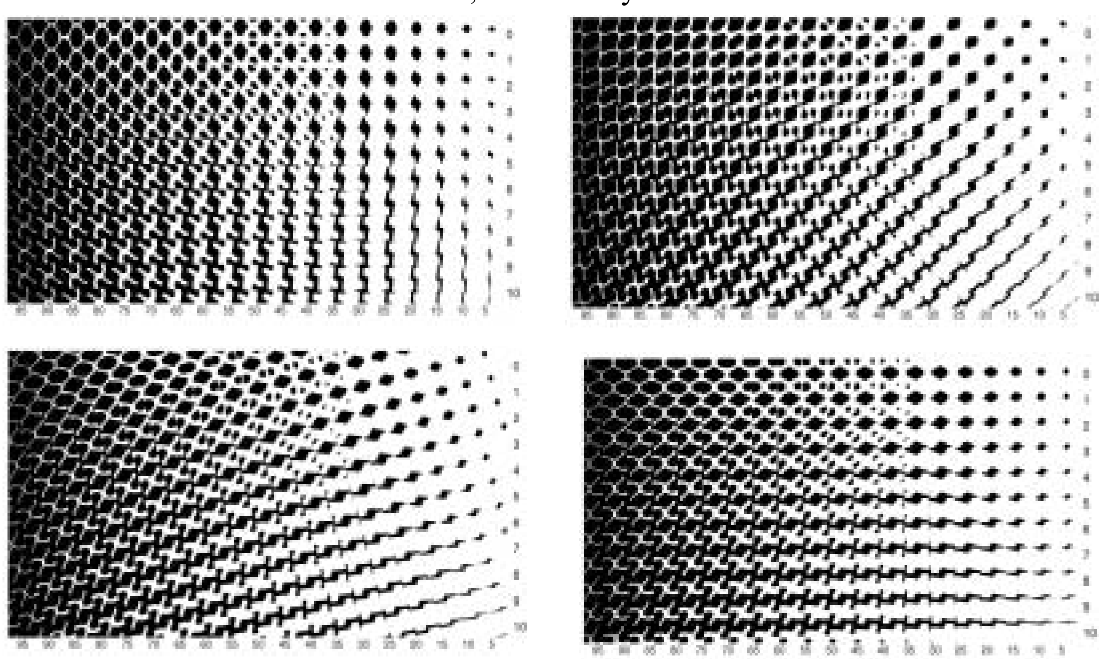


Figure 75 *Mutant screen R73 in gray level (95%-5%) and angle testing (0^0, 45^0, 75^0, 90^0)*

7.4. Design with Mutant Screening

This chapter on parameter change application by which screening cells are defined is intended for elaborating the design with mutating of the known screen element shape. A typical example would be the transformation of a circle screen element into an elliptical one. In the examples there will be variable setting application of values that transform screen elements into originally set shapes.

The first example is the ring shape that transforms into a flattened screen element that keeps its empty center (Fig. 76).

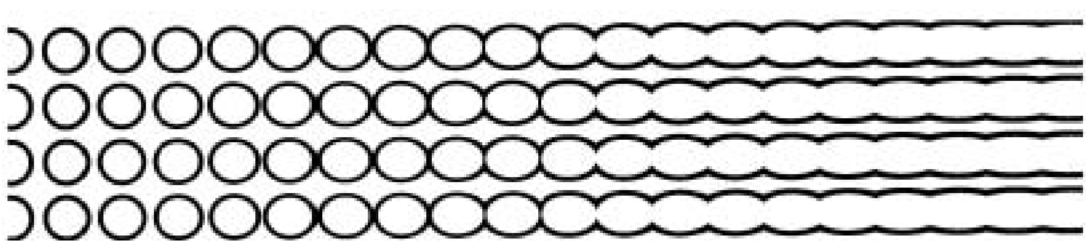


Figure 76 *Flattening of the ring shaped screen element with #bb gray level*

A continuous change of flattening is given from 100 to 60% with a constant gray level value of #bb (hexa, 75%). From the point of two neighboring screen element connections, the ceiling shape flattens and transforms into a flat ceiling line.

The parameter change is applied to the lace screen element (Fig. 77). In this example gray level is determined by value #aa (hex, 69%) and an screen angle of zero degrees.

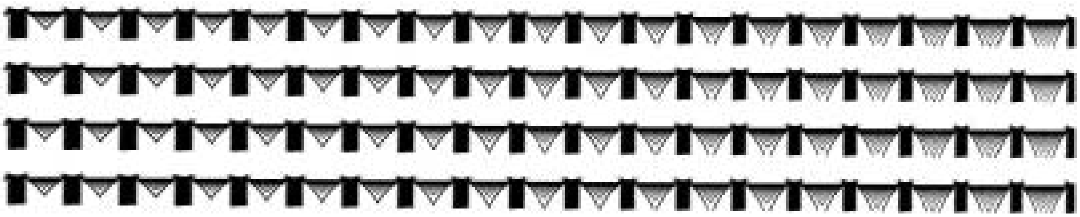


***Figure** 77* *Mutation of lace screen element*

In lace mutation the central screen element shape elongates vertically. It never touches the screening cell border in the here defined gray level. Due to the fact that the same gray level remains throughout the printout, the central body becomes thinner on behalf of the lace central part.

During printing the mentioned two mutant screens can be found in different positions in respect to one another. In Figure 78 both screens are synchronized, noting that the lace screen element is at angle of 90^0.

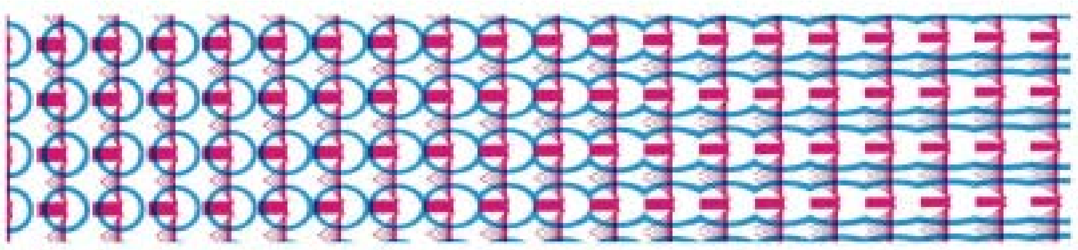


Figure 78 *Distorted lace and ring shaped screen element*

Parameter change in the crystal and net screen element that are exceptionally symmetrical in their general design may cause transition towards closing of their shapes (Fig. 79). Flattening with the same gray level value transforms screen element into a line structure.

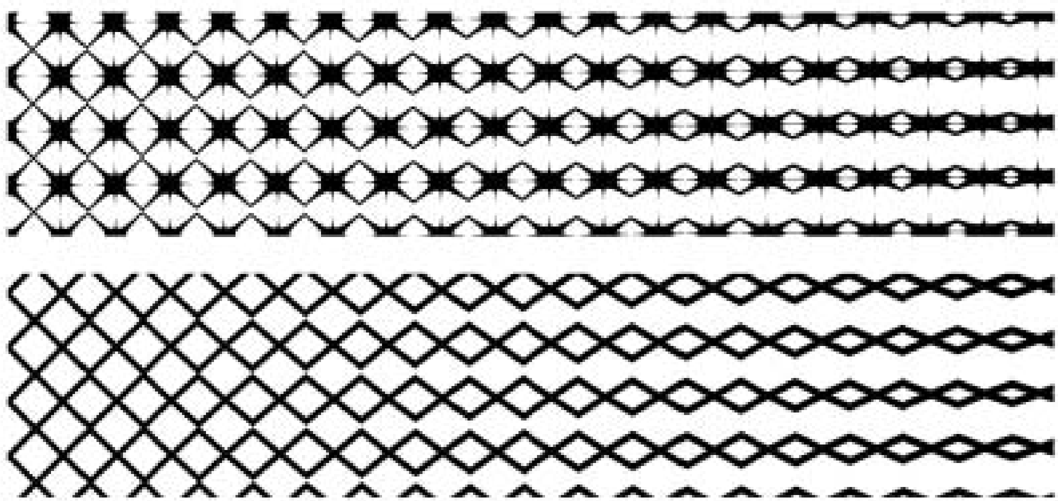


Figure 79 *Mutation of crystal and net screen element*

Action has been left for only the first value that is at the stack top, keeping thus screening element in touch with the neighboring SE. The gray level for these two SE is 69%. Their connection is given in Figure 80.

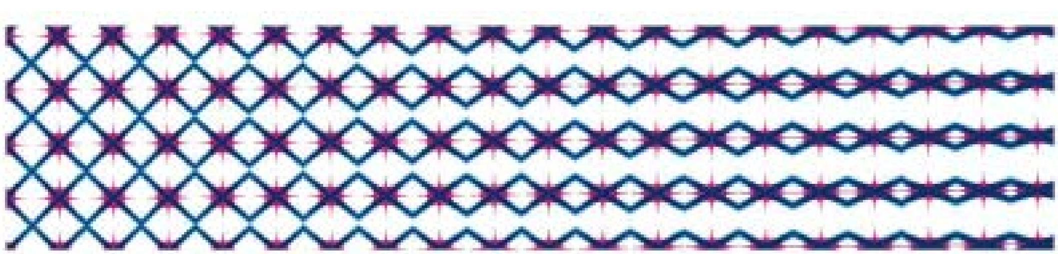


Figure 80 *Connection of the crystal and net screen element*

Security design go level up with mutant screen elements (Fig. 81).

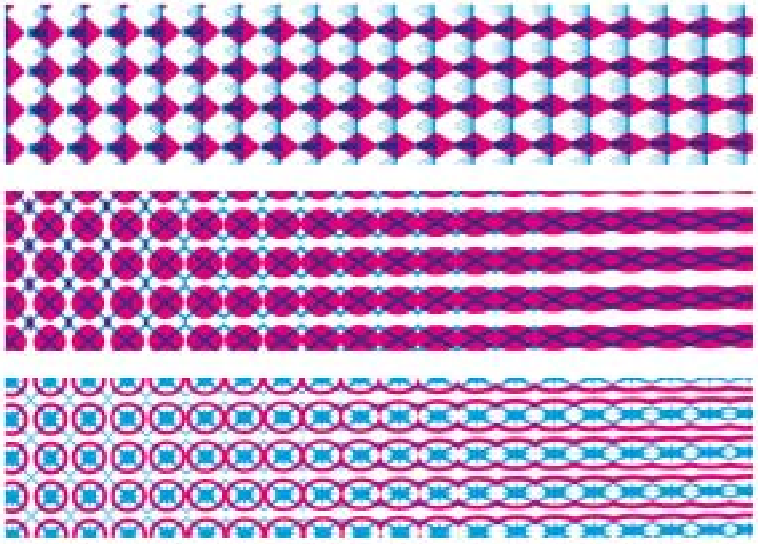


Figure 81 *Flattening of the rhombus, M68, ring and crystal screen shape in security design*

8. Literature

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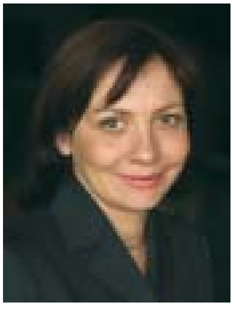

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