

Printing Technology for Orienteering Maps.

Agnar Renolen, August 2010

Introduction

In response to Håvard Tveites brief report on the current work of the IOF mapping committee during WOC2010 in Trondheim this year, I have offered to share with you my knowledge and experience related to production and printing of maps. On a daily basis, I'm working as a cartographer in small mapping company, eMap (www.emap.no). Although we do offer clubs to print orienteering maps, our main focus is topo-maps, city maps and (any) other types of maps.

Particularly regarding topographic maps we have over the last years worked to bring cartography to a new level by exploiting the latest of technology in the printing and graphics industry. In this report I will provide a summary of the elements of these technologies that I consider relevant to orienteering maps.

A Bit of History

When I started to draw my first orienteering map back in 1985, maps were produced by *film sheets* and black ink. These film sheets were combined together in various ways in a reproduction process that resulted in a number of printing plates. These plates were used to transfer a specific spot colour to the paper in an offset printer. This technology was not unique to orienteering, most topographic maps produced by the various national mapping agencies were produced in exactly the same way.

With the advent of the personal computers, maps were digitized and the film sheets were plotted using pen plotters. Apart from the advantage of having the maps stored in a digital format, the advantage of this related to printing is a slight improvement on the line weight consistency. On the other hand, lines would often have a slightly angular appearance as the data points were connected by straight line segments.

The real revolution in printing technology came with *PostScript*, which was introduced by Adobe in 1985. In essence, PostScript is a programming language that could be interpreted by PostScript devices, such as printers and image setters. In other words, PostScript enabled the users to program the appearance of the paper to be printed.

Within five years PostScript was established as an industry standard in the printing and graphics industry. It became possible to produce film negatives for printing plate production directly by printing to image setters. For the mapping industry, this meant that maps could be printed using standard CMYK-colours.

A problem with the CMYK-separations from PostScript, was the lack of sharpness of fine lines such as the brown contours lines whose colour is composed of a mix of several CMYK-values. However, as PostScript is a programming language, it was possible to implement support for spot colours, and many maps were, and still are, printed using spot colours; including orienteering maps.

Later, Adobe introduced the Portable Document Format (PDF) which is a file format derived from PostScript. PDF has now practically replaced PostScript as a standard in the printing and graphics industry. Note that PDF is not a programming language as PostScript is, it is a file format. With PDF 1.4 (2001) Adobe introduced support for transparency in the file format. This is a significant development. Not only did it facilitate more fancy graphics, it also made it possible to emulate spot-colour overprinting in a CMYK-separation.

Before the turn of the century, another revolution hit the printing industry: *Computer to Plate* (CTP). With CTP, the printing plates are “printed” directly from computers eliminating the need for film setting and the associated chemicals. CTP also facilitates better colour accuracy, which again makes it possible to print with a higher halftone resolution.

Finally, we also need to mention the introduction of stochastic halftones, and eventually hybrid halftones. These technologies provides improved colour accuracy and/or higher halftone resolution. As I consider these technologies relevant to maps in general, I will dedicate a section to these later on.

An interesting observation on my side, is that despite these improvements in the printing- and map production process, many maps still tend to look the same way as they did 30 years ago.

In the following sections, I will describe some of these technologies in detail, and discuss how they influence on the orienteering map production process.

Transparency

The original imaging model of PDF was, like PostScript's, opaque: each object drawn on the page completely replaced anything previously marked in the same location. In PDF 1.4 the imaging model was extended to allow transparency. When transparency is used, new objects interact with previously marked objects to produce blending effects [Wikipedia].

There are two parameters that determines the results when two overlapping objects interact with each other. One is the *opacity*, the other is the *blending mode*.

Opacity

In simple, an object's opacity, in combination with the base colour, determines the relative contributions of the base colour, and the blended colour to the resulting composite colour. If the opacity is 0.0, the resulting colour will equal the base colour. If the opacity is 1.0, the blending colour contributes 100% to the resulting colour, but the result depends on the blending mode. [Adobe]

Blending Mode

The blending mode let you vary the ways that the colours of objects blend with the colours of underlying objects. When you apply a blending mode to an object, the effect of the blending mode is seen on any objects that lie beneath the object's layer or group.

It's helpful to think in terms of the following colour terminology when visualizing a blending mode's effect:

- The *blend colour* is the original colour of the selected object, group, or layer.
- The *base colour* is the underlying colour in the artwork.
- The *resulting colour* is the colour resulting from the blend.

In PDF, there are 17 different blending modes, of which three are worth mentioning here.

- *Normal* paints the selection with the blend colour, without interaction with the base colour This is the default mode.
- *Darken* selects the base or blend colour—whichever is darker—as the resulting colour Areas lighter than the blend colour are replaced. Areas darker than the blend colour do not change.
- *Multiply* multiplies the base colour by the blend colour The resulting colour is always a darker colour Multiplying any colour with black produces black. Multiplying any colour

with white leaves the colour unchanged. The effect is similar to drawing on the page with multiple magic markers.

It is also worth mentioning that some of the blending modes produce different results in different colour spaces (RGB, CMYK, CIE etc).

Application to Orienteering Maps.

With orienteering maps, many features are printed with overprinting to avoid features knocking out underlying features. A typical example is contours. Below (Illustration 1) is shown two images that show the appearance of an orienteering map with spot colours with correct overprinting (left), and without overprinting (right).

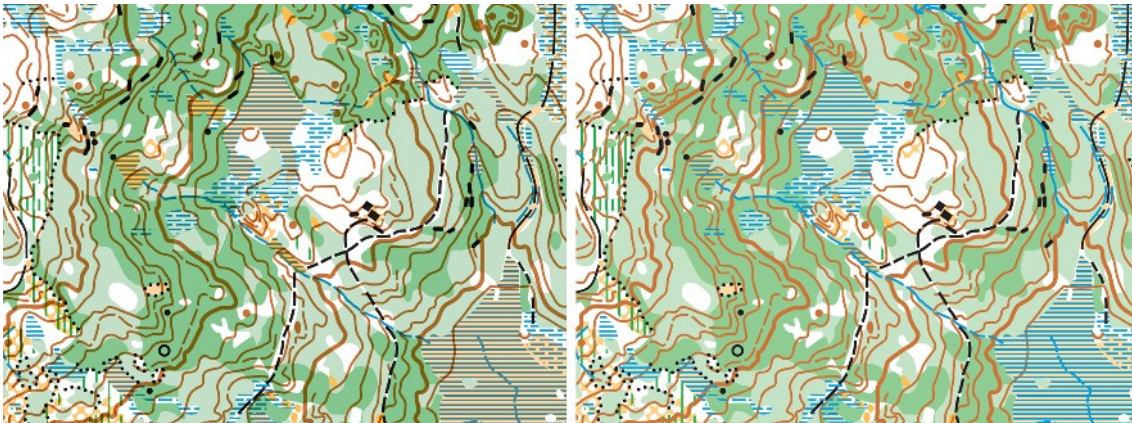


Illustration 1: Spot colours with overprinting (left) and without overprinting (right)

It is obvious that it is the appearance of the left image is the one currently specified in the ISOM2000. If the map is to be printed using four-colour printing, the overprinting effect can be emulated using transparency. Otherwise, the map will be looking like the image to the upper right in the illustration below (Illustration 2). Two blending modes together with 100% opacity produces effects that are close (or identical?) to the spot-colour overprinting effect. The figure below (Illustration 2) illustrates this with *multiply* (lower left) and *darken* (lower right) blending modes for contours, blue and green lines.

It is also possible to emulate the effect using CMYK-overprinting as show in the upper left in the image above (Illustration 2). However this method will not give the most accurate result, but is a good alternative if transparency is unavailable.

Transparency flattening

If a document containing transparency is to be saved or exported to other formats that don't support transparency (such as PostScript), it needs to undergo a process called *flattening*. Flattening divides transparent artwork into vector-based or rasterized areas. As artwork becomes more complex (mixing images, vectors, type, spot colours, overprinting, and so on), so does the flattening process and its results.

If the input graphics is too complex to be flattened into vector graphics on a personal computer (I believe larger orienteering maps can fall into this category), a fall back is to flatten (partly or completely) the graphics into a raster image. However, the quality of this image may not match the quality of the corresponding vector graphics, partly depending on the image resolution. For orienteering maps, we therefore depend on file formats and devices that supports transparency natively.

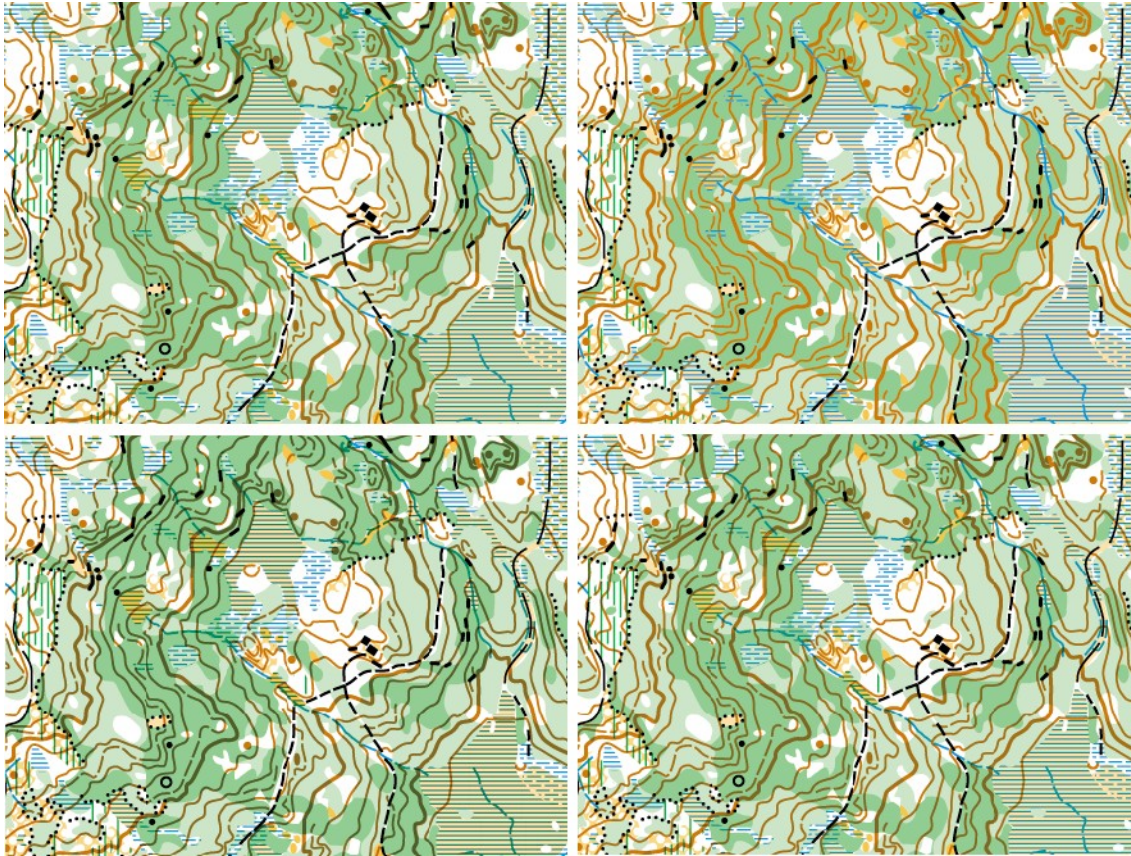


Illustration 2: Various CMYK output using overprint (upper left), without overprint (upper right), multiply transparency (lower left), darken transparency (lower right)

Halftones

Halftone is the reprographic technique that simulates continuous tone imagery through the use of dots, varying either in size or in spacing. Where continuous tone imagery contains an infinite range of colours or greys, the halftone process reduces visual reproductions to a binary image that is printed with only one colour of ink. This binary reproduction relies on a basic optical illusion—that these tiny halftone dots are blended into smooth tones by the human eye. [Wikipedia]

Conventional Halftoning (AM)

Conventional digital halftoning is accomplished by changing the size of printed dots. This technique is often referred to as amplitude-modulated halftone or AM. A typical AM halftoning method, such as cluster dot screening, has very low computational requirements and good print stability. However, it suffers from low spatial resolution and Moiré artefacts.

Stochastic Halftoning (FM)

Newer halftoning techniques such as *stochastic halftones* use identically sized dots, while varying the space between them. This form of halftoning is often referred to as frequency-modulated halftoning or FM. Popular FM halftoning methods, such as error diffusion, can achieve high spatial resolution and are free of Moiré artefacts, but lack the print stability required for electro-

photographic printing. They also need more computational power to calculate. However, it is also said that FM halftones are less prone to small misalignments between printing colours.

Most of you will be familiar with FM halftoning as it is the technique used by most inkjet printers today. But FM-halftoning is now also available in offset printing.

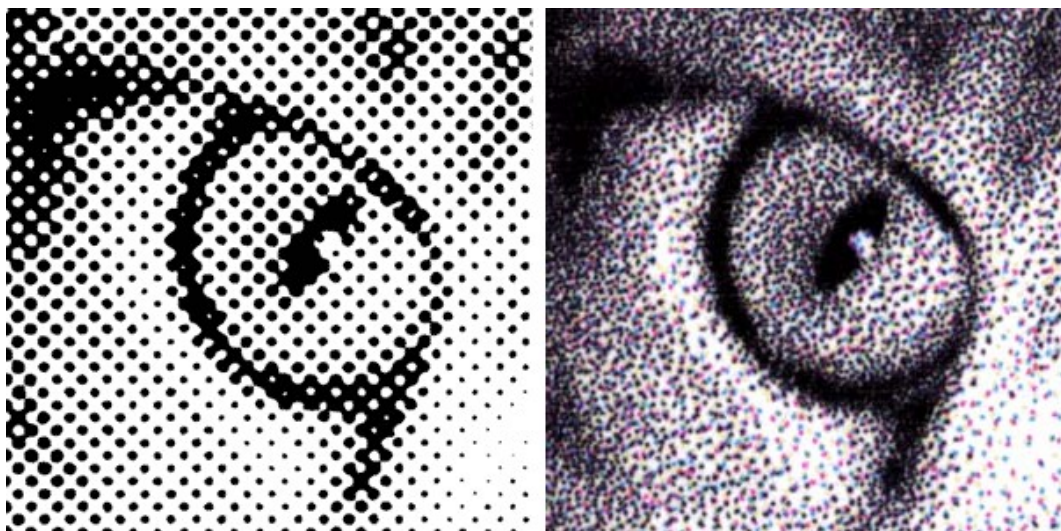


Illustration 3: Conventional AM halftoning (left) and Stochastic FM halftoning (right)

In eMap, we have used FM halftoning on topographic maps printed in four-colours for a number of years, and we are very pleased with the results. Even thin contour lines appear nice and sharp on the map, which was not always the case with AM-halftoning. Contour lines were usually problematic to produce well as we need at least three of the CMYK-components to produce the brown colour. This would result in poor contour quality in a AM-halftoning environment. However, with the advent of CTP technology it is now possible to produce AM-halftoning with a higher resolution and quality than before. This also improves the final result. But we still think FM-halftoning gives the best result.

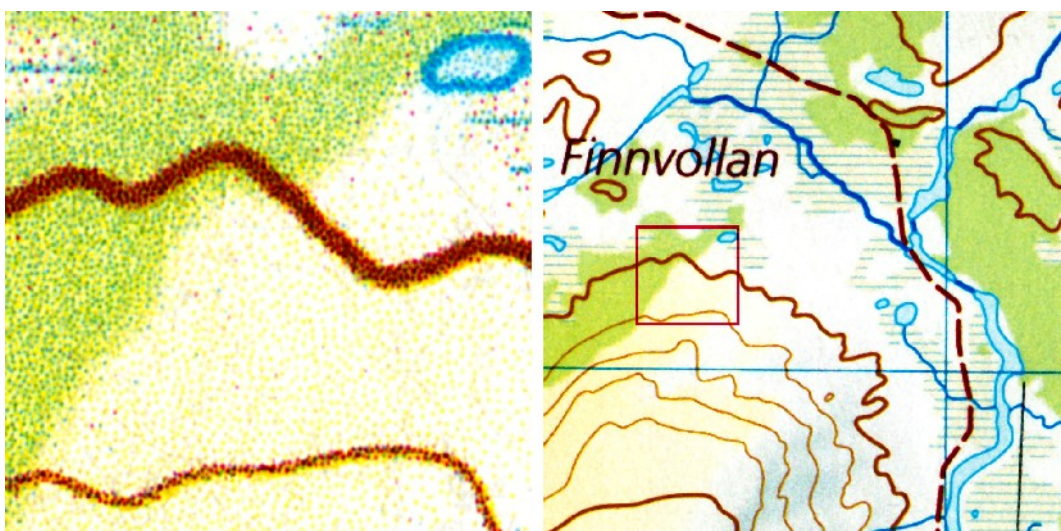


Illustration 4: Map with stochastic FM halftoning

Hybrid Halftoning (AM/FM)

The latest of technology in halftone screening uses a combination of AM and FM screens to produce the result. Classic hybrid halftoning uses a AM halftone along most of the grey scale,

except in the lighter tones where the halftone blends into a FM halftone. The transition from one screen to the other screen occurs over a range of grey levels in such a way that it is not visible to the observer. Another hybrid halftoning technique uses AM dots down to a minimum dot size. Beyond this, AM dots are randomly removed to obtain the lighter tone values.

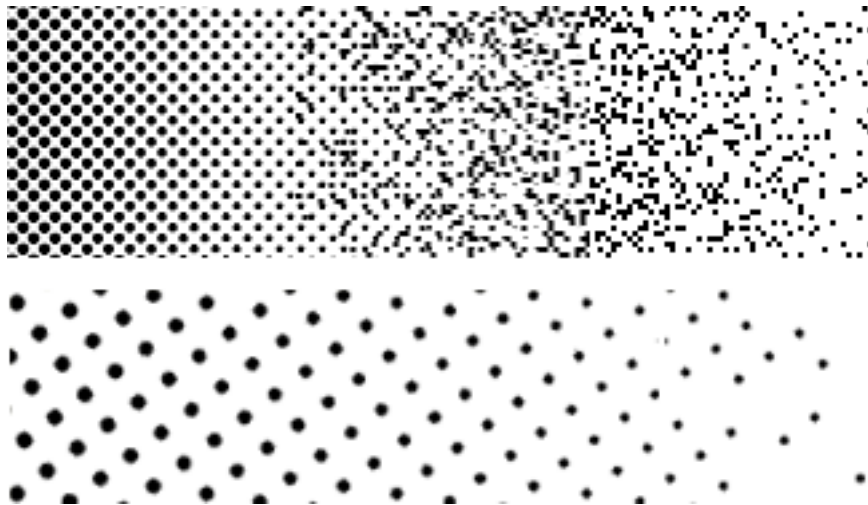


Illustration 5: Hybrid halftoning screens (AM/FM)

Halftoning and Orienteering Maps

Obviously, with spot-colour printing, the use of other than AM halftones makes no sense. There is little variation in the halftone screens needed with colour tints fixed to 20%, 30%, 50% and 60%.

The advantage of the newer halftone screens comes with four-colour printing. Currently, laser printing is approved for minor competitions. I believe that FM halftones together with CTP now provide the necessary quality to allow four-colour printing also for high-level competitions.

PDF and Printing

Portable Document Format (PDF) is an open standard for document exchange. The file format created by Adobe Systems in 1993 is used for representing two-dimensional documents in a manner independent of the application software, hardware, and operating system.

The PDF combines three technologies:

- A subset of the PostScript page description programming language, for generating the layout and graphics.
- A font-embedding/replacement system to allow fonts to travel with the documents.
- A structured storage system to bundle these elements and any associated content into a single file, with data compression where appropriate.

[Wikipedia]

Over the years, PDF has become the standard file format for exchanging data between graphic designers and printing shops. The advantage of PDF over PostScript, is that PDF has a better framework for embedding fonts and other resources that needs to be present to produce the final output. As a result, newer raster image processors (RIPs) are now based on PDF rather than PostScript.

However, despite the improvements of PDF from PostScript, output wasn't always predictable (for example, fonts did not needed to be embedded), and there was subsequently a need to standardize

the content for the PDF-file.

PDF/X is an umbrella term for several ISO standards (15929 and 15930) that define a subset of the PDF format, and that sets up a standard for required content. The purpose of *PDF/X* is to facilitate graphics exchange between the graphic designer and the printing shop to produce predictable results, and it therefore has a series of printing related requirements. For example, in *PDF/X-1a* all fonts need to be embedded and all images need to be CMYK or spot colours. *PDF/X-2* and *PDF/X-3* accept calibrated RGB and CIELAB colours, while retaining most of the other restrictions of *PDF/X-1a*.

Here's a brief summary of some of the *PDF/X* standards:

- *PDF/X-1a:2001*, Blind exchange in CMYK + Spot colours, based on PDF 1.3
- *PDF/X-3:2002*, Allows CMYK, Spot, Calibrated (managed) RGB, CIELAB, with ICC Profile, based on PDF 1.3.
- *PDF/X-1a:2003*, revision of *PDF/X-1a:2001* based on PDF 1.4
- *PDF/X-3:2003*, revision of *PDF/X-3:2002* based on PDF 1.4
- *PDF/X-4*, Colour-managed, CMYK, grey, RGB or spot colour data are supported, as are PDF transparency and optional content.

Submitting Orienteering Maps as PDF

To this point, orienteering maps are most often submitted to printing shops as individual PostScript files, one for each spot colour. As PDF provides a better platform of submitting data for printing, I strongly recommend a transition to PDF-output from mapping software. As a matter of fact, PostScript has practically become obsolete for this purpose.

In the context of orienteering maps, *PDF/X-1a* is sufficient for spot-colour printing. *PDF/X-1a* is a safe format. It is the simplest of the standards, designed to make sure that all printing shops, even those who have older PostScript RIPs can handle the file.

With spot-colour printing, it is also important that colours are named by the Pantone Matching System numbers (PMS), rather than names like "brown", "blue" etc. When the printing shop receives a file with spot colours named "PMS 299", rather than "blue" they know exactly what ink to use (or blend).

Four-colour printing with transparency to emulate spot-colour overprinting requires *PDF/X-4*-compatibility. But, in order to process such files without transparency flattening, a RIP that is compatible with PDF 1.4 is required. Not all printing shops currently have such a RIP.

Digital vs. Offset Printing

Digital printing is a method of printing using digital techniques in which the data and images are printed directly from a computer onto paper. Offset printing on the other hand is a printing technique where the inked image is transferred (or "offset") from a plate to a rubber blanket, then to the printing surface.

Offset printing has traditionally provided the best quality and consistency. It has a larger overhead because of the printing plate production and initial set up of the machinery, but once ready, can print large quantities in a short time.

Digital printing is more slower and more expensive per copy, but involves almost no overhead. Digital printing is therefore favourable in smaller quantities. It has also the advantage that each print can be different. for example, it can be personalized with the name of the receiver or as in orienteering, can be printed with different courses.

Digital printing only provides four-colour printing, but the latest of professional printing machines of this category now offer quality hardly distinguishable from four-colour offset printing. Overprinting is usually also available, but transparency is only available for the newest of machines.

Personal or office laser printers or inkjets, also falls into the category of digital printing. Even if some of these printers offers sufficient quality for minor orienteering races or training events, they usually don't support overprinting nor transparency natively. To get the overprinting effect with these printers, the map graphics has to be flattened. The best way to do this is to flatten or “RIP” the map into an image before printing it.

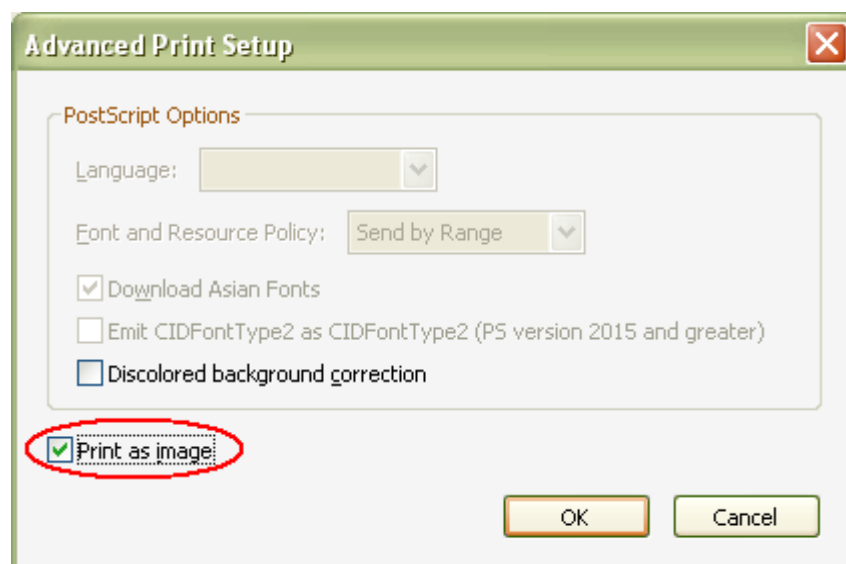


Illustration 6: Advanced printing options in Acrobat

In Adobe Acrobat you can do this directly by clicking [*Advanced*] in the print dialogue, and the check the *Print as image* check box as shown in the image above (Illustration 6). In some versions you can also specify the image resolution.

Paper

Speaking of map printing, it is also worth mentioning a few words on paper and paper qualities. According to ISOM2000, an orienteering map must be printed on good, possibly water resistant, paper (weight 80-120 g/m). In Norway, a paper called “G-print” is normally used. G-print is a matte, coated paper well suitable for maps in general, and is also frequently used by eMap. It is also a reasonably cheap paper, but not very water resistant.

Recently, we have also been offering our customers to print on *Pretex*. Pretex is an established impregnated special paper which is designed for maps that are to be used in the outdoors. It is both water, and tear resistant. Pretex can successfully be printed by all conventional printing methods (except heliogravure printing) and by digital printing (except inkjet). White Pretex-qualities can be printed with common printing inks for normal paper.

Pretex is more expensive than G-print. On a topographic map if size 100x70cm, we estimate an increase in final product price of about 2 Euros per map.

One of our customers had a flooding in his cellar where he stored a large stock of Pretex maps on the floor. The water raised to about 30cm above the floor, soaking the maps under the water line. However, after a couple of weeks of careful drying, he managed to recover all maps completely without visible defects.

I believe orienteering maps is a perfect match for Pretex (or similar) paper. I strongly recommend the IOF mapping committee to support testing of Pretex in competitions, with and without plastic

envelopes.

There are also other paper qualities designed for maps and outdoor use on the market. It is worth investigating some of these paper qualities as well, and check out the prices.

From internet shops, you can also buy waterproof/weatherproof papers from the USA, designed for your home or office printer. They come in packages of 10, 25, 50 or even 200 sheets, usually in sizes of 8½x 11 or 11x17 inches. It also worth trying some of these papers. (check out <http://www.waterproof-paper.com/>)

Discussion

As a general conclusion I believe the future of orienteering map printing is four-colour printing. I believe that stochastic halftone screening (FM) and correct use of transparency together with the newest in printing technology can produce maps that have the same legibility that spot-colour printed maps provide today.

However, there are pitfalls. Many printing shops still operate old machinery and software. A successful result requires a production line that ends up in a PDF/X-4 compatible file, and a printing shop that have a RIP compatible with PDF 1.4. Not all printing shops deliver stochastic halftones either.

Nonetheless, the technology is already here, and will spread during the coming years. However, we need the competence and the tools to use it. I strongly recommend the IOF mapping committee to conduct experiments with these technologies (I'll be happy to assist you in this process) and compare the results.

The main advantage of four-colour printing over spot-colour printing is lower printing cost, and the possibility to introduce more colours into the map without further cost. For example, it is possible to eliminate some of the hatches and patterns in favour of different colours, thus creating a more readable map.

I believe the most critical part is the legibility of contours. If the newest technology is considered insufficient to print legible contours using four-colour printing, it is possible to take out the contours on a separate plate, and print the remaining colours using CMYK separation. This should still provide a lower cost than full five or six plate spot colour printing (In this case it is also worth considering replacing the blue colour, PMS 299, with pure cyan, to avoid moire artefacts on marshes).

If there are further questions, don't be shy to contact me on agnar.renolen@emap.no.