Dig\textsuperscript{1}D\textsuperscript{ür}er – a digital engraving system

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A variety of halftone methods for reproducing gray-level images on bilevel display media have been proposed. The output of even the best of these falls far short of the quality achieved on similar resolution media in man-made engravings. We introduce \textit{Dig\textsuperscript{1}D\textsuperscript{ür}er} – a digital engraving/halftoning system. For a gray-level image input, the system produces a bilevel (black and white only) picture, which has the appearance of an engraving of the input. The system produces high-quality output, even when the graphic elements of the halftone are visible, and both the quality and style of the output can be improved or customized either by using further information on the image content or by interactive user intervention. The heart of \textit{Dig\textsuperscript{1}D\textsuperscript{ür}er} is a curve evolution algorithm generating halftones by controlling the density of line elements, which are the level contours of a potential field induced by the image via an Eikonal equation. Since the basic version of the system produces rather rough results, further capabilities were added to allow for user intervention and the use of image content information. Extensions to graphic elements other than lines are also feasible.

\textbf{Key words:} Digital halftone – Bilevel display – Curve evolution – Expert systems

1 Introduction

A picture is worth a thousand words. Part of the reason is the seemingly infinite variety of tones one can find in it. However, some of the most important mediums for the display of pictures are bilevel ones. The most prominent of these is the printed medium, where every point in an image is either black (with ink) or white (no ink). Other such mediums include many types of terminals that are either bilevel (such as LCDs or monochromes) or else support only a limited variety of shades. To display a gray-level picture on such a medium we must use a process called halftoning, which transforms the original into a bilevel, binary picture that can be displayed.

There are quite a few strategies and algorithms for digital halftoning. Ulichney (1987) lists the most important of them: clustered ordered dither, dispersed ordered dither, and error diffusion techniques (Fig. 1 a–d). Other methods include those of Knuth (1987), Kollias and Anastassiou (1991), Peli (1991), Sullivan et al. (1991) and more. All these methods have several properties in common:

- They are inherently digital – that is, they can be viewed as transformations of pixels into pixels.
- When the pixel grid is fine (so that individual pixels cannot be seen) many of them achieve a quality that is between acceptable and excellent.
- When the grid is coarse (so that individual pixels are noticeable) the quality is considerably degraded.

A nondigital method that in essence shares these properties is the halftone screen (Harrop 1968; Ulichney 1987) used for most picture reproductions in printing presses to date. It is a photomechanical analog method that produces dots of varying sizes according to the local grayness at the position of the dot.

Before mechanized methods became available, the need to display gray-level pictures on a bilevel medium (mainly ink on paper) was met by artists or craftsmen who specialized in the production of pictures composed of single tone elements on a background of contrasting tone. Engraving, etching, woodcutting and lithography are the most common of the variety of styles and techniques used by these human masters, see Ivins 1985, 1988. (The word halftone is itself a translation of the Italian mezzotint – the name of one such technique.) Figure 2a–c are examples of the impressive achievements of man-made halftones.

Despite the large variety, there are a few things
Fig. 1a–d. Common digital halftone methods: a clustered order dither; b dispersed order dither; c error diffusion – the Floyd-Steinberg method; d error diffusion method (Jarvis et al. 1976)

Fig. 2a–c. Examples of man-made halftones: a “Erasmus of Rotterdam” by A. Dürer (Strauss 1973); b “The Bagpiper” by A. Dürer (Strauss 1973); c “A Classical Head” engraved for the Society of Dilettanti, London, 1809 (Ivins 1988)