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Directional difference chain codes with quasi-lossless compression and run-length encoding

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ABSTRACT

This paper considers a new contour-based representation of binary objects in raster images. Low processing and storage requirements of the decoder, satisfactory compression ratio and generality make this chain coding technique interesting for storing predefined graphical objects in embedded systems. Three improvements of the DDCC code were introduced. Extra Huffman codes are assigned to two frequent pairs of symbols, 135° directional differences in concave angles are omitted since they do not affect the outer object shape and, finally, longer line segments are run-length encoded. Comparison with six other chain coding techniques of similar implementation complexity confirms that the new technique represents an efficient alternative way to encode 8-connected contours.

1. Introduction

Chain codes provide an efficient contour-based representation and compression of binary objects in raster images. They can be viewed as a connected sequence of straight-line segments along the object's contour, with specified lengths and directions. Typically, the lengths are reduced to distances between adjacent pixels and need not be explicitly coded. The chain coding techniques are often used in image processing [4,9,20], pattern recognition [10,12], computer graphics [8,21,26], and multimedia applications [17–19]. The main reason for their popularity is their compactness. For example, discrete objects extracted from a raster map and stored in raster cartographic layers, including the topological features (e.g. mountain ridges), line objects (railways), polygon objects (states, buildings), iso-contours, and even the appearances of geographic names in the map, can be efficiently represented by chain codes. On the other hand, the chain codes can be used to store a collection of predefined raster objects, aimed for visualisation in systems with weak processing power. Globačnik and Žalik [8] presented a practical case of using predefined raster font characters in embedded systems for home appliances. Our main motivation is a chain coding technique applicable for wider repertoire of graphical objects, besides the font characters, and with better compression ratio, but with similarly low processing and storage requirements of the decoder, in comparison with the C_VCC method [14] adapted by Globačnik and Žalik.

The first chain coding technique was introduced by Freeman in 1961 [5]. The *Freeman chain code (FCC8)* has remained the most widely used chain coding technique in practice, due to its simplicity. It describes moves along a sequence of adjacent pixels using absolute directions based on 8-connectivity. The direction is encoded by using the numbering scheme $\{i|i=0, 1, 2, \ldots, 7\}$ denoting an angle of $45^\circ \times i$ anticlockwise from the positive x-axis (see Fig. 1(a)). A *4-directional version of the Freeman chain code (FCC4)* is sometimes used, too. Here the direction from pixel P

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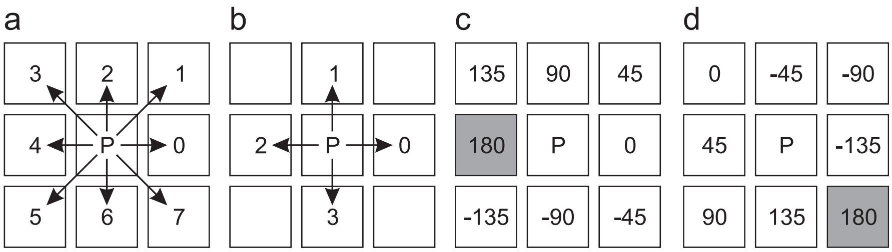

Fig. 1. Pixel-based chain codes are either based on absolute directions: (a) FCC8; (b) FCC4; or on directional differences: (c) DDCC after moving east; (d) DDCC after moving northwest.

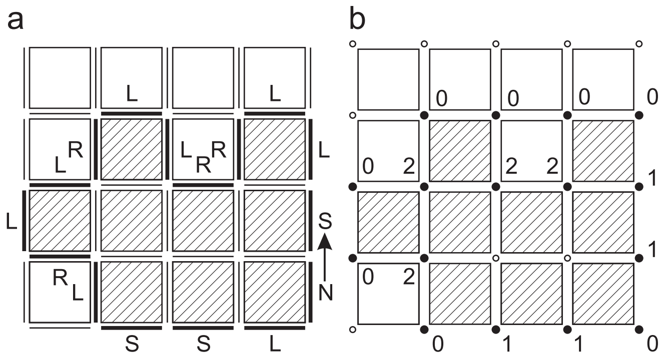

Fig. 2. (a) Edge-based differential chain code—DCC; (b) vertex-based chain code—VCC of three symbols.

(Fig. 1(b)) to its successor is coded according to the numbering scheme $\{i | i=0, 1, 2, 3\}$ denoting an angle of $90^\circ \times i$ counter-clockwise from the positive x-axis.

Kaneko and Okudaira [11] proposed an efficient encoding algorithm for digital curves, which utilises the property that a curve with gentle curvature is divided into somewhat long segments, each of which is represented by a sequence of two adjacent codes from the FCC8 coding scheme. Complicated curves obtained from geographic maps have been compressed to 50–60 per cent of that required by the FCC8. A similar compression can be achieved by conceptually much simpler *directional difference chain code (DDCC)*, proposed by Liu and Žalik [13]. This technique codes each line segment in the chain as a relative angle difference between it and the previous segment. In Fig. 1(c), pixel P is approached from the left (west) and, therefore, the movement to the right (east) was performed in its predecessor (coloured grey). In Fig. 1(d), P is reached in the northwest (upper left) direction from its southeast (bottom right) neighbour. The values in these two figures show possible angle differences (in degrees), which should be coded in P if the chain proceeds to the corresponding adjacent pixel. Obviously, the arrangement of values depends on the relative position of the predecessor of P. The authors actually elaborated the *chain-difference coding scheme* proposed by Freeman [6], compressed the resulting codes using Huffman coding, and performed extensive tests on over 1000 shape outlines, open and closed curves. Sánchez-Cruz et al. [23] refer to DDCC as the *angle Freeman chain code of eight directions (AF8)* while it is called the *differential Freeman chain code of eight directions (DFCCE)* in [24]. Nevertheless, both sources confirm the efficiency of DDCC. A three-symbol variant of DDCC was introduced in [23], and named the *orthogonal chain directions of three symbols (3OT)*. Sánchez-Cruz and Rodríguez-Díaz [24] slightly improved the compression by replacing the Huffman coding with an arithmetic coding, in both DDCC (DFCCE) and 3OT. Sánchez-Cruz [25] recently proposed the *modified directional Freeman Chain code in eight directions by a set of nine symbols* (MDF9). He uses practically the same improvements of DFCCE as we propose for DDCC in this paper, but there are also several significant differences between both methods, which we list at the end of Section 2.

In the aforesaid techniques, raster curves are modelled as chains of pixels. Nunes et al. [17] proposed a different model: hexagonal grid based on edge sites. Assuming that the pixels are structured within a rectangular grid, the hexagonal edge grid corresponds to all the sites located between two adjacent pixels, extended to the image borders [18]. The edge-based chain codes can be either based on absolute directions or on directional differences, analogously to the pixel-based representations. The *differential chain code (DCC)* unambiguously represents each edge by one of three possible directional differences from the set {R=Turn Right; L=Turn Left; S=Straight Ahead} (Fig. 2(a)). The first edge stores its location and initial direction (N=North in Fig. 2(a)). The authors [17,18] proposed lossless shape coding with Huffman-compressed DCC, but also a quasi-lossless shape coding based on a so-called *multiple grid chain code* (*MGCC*). The latter was introduced by Minami and Skinohara [16] to encode line drawings, adapted to image contour coding by