Morphological Image Interpolation to Magnify Images with Sharp Edges

Valérie De Witte[1], Stefan Schulte[1], Etienne E. Kerre[1]
Alessandro Ledda[2], and Wilfried Philips[2]

[1] Ghent University
Department of Applied Mathematics and Computer Science
Fuzziness and Uncertainty Modelling Research Unit
Krijgslaan 281 (Building S9), B-9000 Gent, Belgium
[2] Telin Department - IPI Group
Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium
Valerie.DeWitte@UGent.be
http://www.fuzzy.ugent.be

Abstract. In this paper we present an image interpolation method, based on mathematical morphology, to magnify images with sharp edges. Whereas a simple blow up of the image will introduce jagged edges, called 'jaggies', our method avoids these jaggies, by first detecting jagged edges in the trivial nearest neighbour interpolated image, making use of the hit-or-miss transformation, so that the edges become smoother. Experiments have shown that our method performs very well for the interpolation of 'sharp' images, like logos, cartoons and maps, for binary images and colour images with a restricted number of colours.

1 Introduction

Image interpolation has many applications such as simple spatial magnification of images (e.g. printing low-resolution documents on high-resolution printer devices, digital zoom in digital cameras), geometrical transformation (e.g. rotation), etc. Different image interpolation methods have already been proposed in the literature, a.o. [[1] - [11]]. In this paper we will describe a new morphological image interpolation technique, for binary images as well as for colour images with a limited number of colours, with sharp edges. First we review some basic definitions of mathematical morphology, including the hit-or-miss transformation. In section 3 we introduce our new interpolation approach. We explain the pixel replication or nearest neighbour interpolation, used as the first 'trivial' interpolation step in our method. Thereafter we discuss our corner detection method, using different kinds of structuring elements, and describe our corner validation, first for magnification by a factor 2 and then for magnification by an integer factor $n > 2$. Finally, in section 4 we have compared our interpolation method experimentally to other well-known approaches. The results show that our method provides a visual improvement in quality on existing techniques: all jagged effects are removed so that the edges become smooth.

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2 Basic Notions

2.1 Modelling of Images

A digital image I is often represented by a two-dimensional array, where (i, j) denotes the position of a pixel $I(i, j)$ of the image I.

Binary images assume two possible pixel values, e.g. 0 and 1, corresponding to black and white respectively. White represents the objects in an image, whereas black represents the background. Mathematically, a 2-dimensional binary image can be represented as a mapping f from a universe X of pixels (usually X is a finite subset of the real plane $\mathbb{R}^2$, in practice it will even be a subset of $\mathbb{Z}^2$) into $\{0, 1\}$, which is completely determined by $f^{-1}(\{1\})$, i.e. the set of white pixels, so that f can be identified with the set $f^{-1}(\{1\})$, a subset of X, the so-called domain of the image. A 2-dimensional grey-scale image can be represented as a mapping from X to the universe of grey-values $[0, 1]$, where 0 corresponds to black, 1 to white and in between we have all shades of grey. Colour images are then represented as mappings from X to a 'colour interval' that can be for example the product interval $[0, 255] \times [0, 255] \times [0, 255]$ (the colour space RGB). Colour images can be represented using different colour spaces; more information about colour spaces can be found in [13], [14].

2.2 Binary and Colour Morphology

Consider a binary image X and a binary structuring element A, which is also a binary image but very small in comparison with X. The translation of X by a vector $y \in \mathbb{R}^n$ is defined as $T_y(X) = \{x \in \mathbb{R}^n \mid x - y \in X\}$; the reflection of X is defined as $-X = \{-a \mid a \in X\}$.

Definition 1. *The binary dilation $D(X, A)$ of X by A is the binary image*

$$D(X, A) = \{y \in \mathbb{R}^n \mid T_y(A) \cap X \neq \emptyset\}.$$

The binary erosion $E(X, A)$ of X by A is defined as

$$E(X, A) = \{y \in \mathbb{R}^n \mid T_y(A) \subseteq X\}.$$

The dilation enlarges the objects in an image, while the erosion reduces them.

Property 1. *If A contains the origin (i.e. $\mathbf{0} \in A$), then*

$$E(X, A) \subseteq X \subseteq D(X, A).$$

With this property the binary image $D(X, A) \backslash E(X, A)$ can serve as an edge-image of the image X, which we call the morphological gradient $G^A(X)$ of X. Analogously we define the external morphological gradient $G^{A,e}$ and the internal morphological gradient $G^{A,i}$ as

$$G^{A,e}(X) = D(X, A) \backslash X \quad \text{and} \quad G^{A,i}(X) = X \backslash E(X, A),$$