

Chapter 50

Object Recognition via Contour Points Reconstruction Using Hurwitz – Radon Matrices

Dariusz Jakóbczak

Technical University of Koszalin, Poland

ABSTRACT

Object recognition is one of the topics of artificial intelligence, computer vision, image processing and machine vision. The classical problem in these areas of computer science is that of determining object via characteristic features. Important feature of the object is its contour. Accurate reconstruction of contour points leads to possibility to compare the unknown object with models of specified objects. The key information about the object is the set of contour points which are treated as interpolation nodes. Classical interpolations (Lagrange or Newton polynomials) are useless for precise reconstruction of the contour. The chapter is dealing with proposed method of contour reconstruction via curves interpolation. First stage consists in computing the contour points of the object to be recognized. Then one can compare models of known objects, given by the sets of contour points, with coordinates of interpolated points of unknown object. Contour points reconstruction and curve interpolation is possible using new method of Hurwitz - Radon Matrices.

INTRODUCTION

Method of Hurwitz - Radon Matrices (MHR), invented by the author, can be applied in reconstruction and interpolation of curves in the plane. The method is based on a family of Hurwitz - Radon (HR) matrices. The matrices are

skew - symmetric and possess columns composed of orthogonal vectors. The operator of Hurwitz - Radon (OHR), built from these matrices, is described. Author explains how to create the orthogonal and discrete OHR and how to use it in a process of curve interpolation and modeling. Proposed method needs suitable choice of nodes, i.e. points of the curve to be reconstructed; nodes should be settled at each extremum (minimum

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or maximum) of one coordinate and at least one point between two successive local extrema, and nodes should be monotonic in one of coordinates (for example equidistance). Created from the family of $N - 1$ HR matrices and completed with the identical matrix, system of matrices is orthogonal only for vector spaces of dimensions $N = 2, 4$ or 8 . Orthogonality of columns and rows is very important and significant for stability and high precision of calculations. MHR method is modeling the curve point by point without using any formula of function. Main features of MHR method are: accuracy of curve reconstruction depending on number of nodes and method of choosing nodes, interpolation of L points of the curve is connected with the computational cost of rank $O(L)$, MHR interpolation is not a linear interpolation. The problem of curve length estimation is also considered. Algorithm of MHR method and the examples of object recognition are described.

BACKGROUND

The following question is important in mathematics and computer sciences: is it possible to find a method of curve interpolation in the plane without building the interpolation polynomials? This chapter aims at giving the positive answer to this question. Current methods of curve interpolation based on classical polynomial interpolation: Newton, Lagrange or Hermite polynomials and spline curves which are piecewise polynomials (Dahlquist & Björck, 1974). Classical methods are useless to interpolate the function that fails to be differentiable at one point, for example the absolute value function $f(x) = |x|$ at $x = 0$. If point $(0;0)$ is one of the interpolation nodes, then precise polynomial interpolation of the absolute value function is impossible. Also when the graph of interpolated function differs from the shape of polynomials considerably, for example $f(x) = 1/x$, interpolation is very hard because of existing local

extrema of polynomial. We cannot forget about the Runge's phenomenon: when interpolation nodes are equidistance then high-order polynomial oscillates toward the end of the interval, for example close to -1 and 1 with function $f(x) = 1/(1+25x^2)$ (Ralston, 1965). MHR method is free of these bad examples. Computational algorithm is considered and then we have to talk about time. Complexity of calculations for one unknown point in Lagrange or Newton interpolation based on n nodes is connected with the computational cost of rank $O(n^2)$.

The classical problem in machine vision, computer vision (Ballard, 1982) and image processing is that of determining whether or not the image data contains some significant and specific features or objects. Contour of the object consists of information which allows to describe many important features of the object. Analysis of the object shape has to be done in the process of image detection and recognition. There are other methods of contour reconstruction than interpolation. Digital curve (open or closed) may be represented by chain code (Freeman's code). Chain code depends on selection of the started point and transformations of the object. So Freeman's code is one of the method how to describe and to find contour of the object. Analog (continuous) version of Freeman's code is the curve $\alpha - s$. Another contour representation and reconstruction is based on Fourier coefficients calculated in Discrete Fourier Transformation (DFT). These coefficients are used to fix similarity of the contours with different sizes or directions. If we assume that contour is built from segments of a line and fragments of circles or ellipses, Hough transformation is applied to detect contour lines. Also geometrical moments of the object are used during the process of object recognition (Choraś, 2005). Edge detection is one of crucial points in shape analysis and object recognition (Pratt, 2001). MHR method requires to detect specific points of the object contour, for example in compression and reconstruction of monochromatic medical images (Jakóbczak & Kosiński, 2007). Contour

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