LENGTH ESTIMATORS FOR TWO DIMENSIONAL AND THREE DIMENSIONAL IMAGES USING RELATIVE DIRECTION CHAIN CODE

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To my late father, who is in my heart forever.

To my beloved mother and sister, who have sacrificed a lot in order for me to further my education.

To my friend Lili who has tolerated me all the time and taught me the virtue of being patient.

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ABSTRACT

The normal practice of representing an image is in digitized form. Although digitization provides no knowledge about the continuous shape but by the assistance of discrete geometric estimators such as length estimators, it is possible to obtain the feature size. In digitization, two widely used chain code schemes for shape representation are Freeman and Bribiesca chain code. The Freeman chain code (FCC) is based on absolute direction while Bribiesca chain code is based on relative direction which makes it stable in shifting, turning, and mirroring movement of image. The main purpose of this study is to implement the relative direction chain code or so-called Bribiesca chain code in length estimator algorithms. This study can be divided into two main parts. The first part is to develop two-dimensional (2D) local and global length estimator based on Bribiesca vertex chain code (VCC). For local length estimator, all regular grids namely rectangular, hexagonal and triangular are applied. For global length estimator, only rectangular grid is considered. The second part is to develop three-dimensional (3D) local length estimator based on Bribiesca Orthogonal Directional Change Chain Code (ODCCC). The process is divided into quantization of curve, chain code extraction, and development of length estimators. In quantization, different methods are implemented such as Grid Intersection Quantization, Grid Intersection-Enneagon Quantization, and Cube Quantization. There are four equations and one algorithm proposed for length estimation. The results of the proposed methods are promising such that the length estimators for 2D and 3D images become independent from starting point, and also the 2D global length estimator covers offline and online algorithm. Finally the comparison between the proposed and the established length estimators by FCC gives similar performance, however the resultant visualization of proposed algorithm works better.

ABSTRAK

Amalan mewakili satu imej biasanya adalah dalam bentuk digital. Walaupun pendigitan tidak menyediakan maklumat tentang bentuk selanjar tetapi dengan bantuan penganggar geometri diskret seperti penganggar panjang, ia berkemungkinan untuk mendapatkan ciri saiz. Dalam pendigitan ,dua skema kod rantai yang digunakan secara meluas untuk mewakili bentuk adalah Freeman dan kod ranti Bribiesca. Freeman kod rantai (FCC) adalah berasarkan kepada arah mutlak manakala kod rantai Bribiesca berdasarkan kepada arah relatif yang membuatkan ia menjadi stabil dalam pemindahan, pusingan, dan pergerakan pencerminan imej. Tujuan utama kajian ini adalah untuk melaksanakan hubungan arah kod barantai atau dipanggil kod rantai Bribiesca dalam algoritma penganggar panjang. Kajian ini terbahagi kepada dua bahagian. Bahagian pertama adalah bagi membangunkan penganggar panjang 2D global dan setempat berdasarkan bucu Bribiesca kod rantai (VCC). Untuk penganggar panjang tempatan, semua grid tetap seperti kekisi segi empat tepat, segi enam dan segitiga digunakan. Untuk penganggar panjang global, hanya kekisi segi empat tepat dipertimbangkan. Bahagian kedua adalah bagi membangunkan penganggar panjang 3D setempat berdasarkan Bribiesca Orthogonal Directional Change Chain Code (ODCCC). Proses ini terbahagi kepada pengkuantuman lengkung, pengekstrakan kod rantai, dan pembangunan penganggar panjang. Terdapat empat persamaan dan satu algoritma dicadangkan untuk penganggar panjang. Hasil kajian adalah memberansangkan dimana kedua-dua penganggar panjang 2D dan 3D didapati menjadi tidak bergantung kepada titik permulaan. Disamping itu, dibuktikan juga bahawa penganggar panjang 2D global dapat digunakan untuk kedua-dua situasi diluar talian dan diatas talian. Akhirnya, perbandingan diantara algoritma yang dicadangkan dengan panjang penganggar sedia ada yang dikemukakan oleh FCC adalah hampir sama dari segi pelaksanaan, walaubagaimana pun dari segi visualisasi, algoritma yang dicadangkan adalah lebih baik berbanding algoritma yang sedia ada.

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LIST OF ABBREVIATIONS

2D	Two Dimension
3D	Three Dimension
BQQ	Background Boundary Quantization
CAE	Computer-aided Engineering
CQ	Cube Quantization
CT	CAT Scanning
DR95	Algorithm Debled-Rennesson and Reveilles 1995
DSS	Digital Straight Segment
EQ	Enneagon Quantization
FCC	Freeman Chain Code
GIQ	Grid Intersection Quantization
GIS	Geographic Information System
H_VCC	Hexagonal Vertex Chain Code
MLQ	Maximum Length Quantization
MPL	Minimum Polygonal Length
MRI	Magnetic Resonance Imaging
OBJ	Object file format for 3D object
OBQ	Object Bouandary Quantization
ODCCC	Orthogonal Direction Chain Code
R_VCC	Rectangular Vertex Chain Code
RDEV	Root Mean Square Deviation
T_VCC	Triangular Vertex Chain Code
TBI	Thinned Binary Image
TCQ	Thinned Cube Quantization
VCC	Vertex Chain Code

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CHAPTER 1

INTRODUCTION

1.1 Introduction

For centuries human beings have been trying to get the information which convey on the scenes. In this century with the development of electronic devices, there is more effort to achieve this goal. Image analysis is one of the methods to draw facts of nature. In many fields such as medical imaging, range image processing, image sequence analysis, and robotic navigation, shape analysis becomes critical. Different techniques in image analysis accomplish this purpose such as pattern recognition. In pattern recognition, an implementation of image features makes it probable to extract information from the image. Therefore, one of the aims of image analysis is extracting and analyzing information such as the length of digital straight segments in image by the assistance of different features such as the chain code.

In General image processing is divided to three steps. First is low-level processing which aim is to apply primitive operation such as noise reduction, contrast enhancement, and sharpening image. This level is recognised by the fact that both inputs and outputs are images. Mid-level is the second level in this category. This level consists of segmentation, description, and classification of individual objects in the image. In this step, the inputs are images but the outputs are features or attributes obtained from the image. The last level is high-level which makes sense from the output of previous level (Jähne, 2005). This categorization is helpful to understand the position of this work in image processing. This work is focussed on mid-level and high level. Chain code belongs to the image feature group which belongs to mid-level, and it is the representation of the digitized curve. The most important concept to derive the chain code from the shape is the method for discretization. The relative direction based chain codes for two dimensional and three dimensional are proposed by Birbiesca (2000). These chain codes have advantages over the other chain coding techniques. The chain code scheme is the data for length estimation which is one of the important elements in shape analysis. The length estimators belong to high-level step in image processing task. The main complication in length estimation is that the original length should be estimated from the digitization presentation. Therefore, the unambiguous schemes in order to acquire this representation are crucial. In addition, it leads to the precious estimation of the length segments.

This study implements a new kind of chain code in two dimensional and three dimensional images for estimating the length of digital straight segments in thinned binary image. The results are new formulations for local length estimators based of the characteristics of this chain code and also global length estimator in two dimension.

1.2 Background of the Problem

This study deals with the implementation of relative direction chain code in length estimators. The chain code background and the problem of the previous chain code applied in the length estimators are considered.

1.2.1 Chain Code

Chain code is introduced by Freeman (1974) for two dimensional and three dimensional line structures, this notation depends on absolute direction. The two dimensional (2D) chain code is proposed for 4-connectivity or 8-connectivity pixels; it has 4 digits or 8 digits, respectively. This chain code is invariant with translation over the grid even though by rotating and mirroring movement, the result will change. The 3D chain code is based on quantization of line structure on a cubic lattice and it composes of 26 digits which are based on direction while a different notation as a descriptor of canonical shape for three dimensional sticks body is proposed by Guzman (1987). It is a description of the juxtaposition limb or the structure of the body. The chain is called base-five digit (‘0’, ’1’, ’2’, ‘3’, ‘4’) which describes the sequence of 3D turns composing of Limb string. In this descriptor, besides these five digits, another notation is required to describe the shape completely. As the definition complies, this chain code is facing complications.

The chain codes problem has become lighter by a new chain code. Bribiesca (1999, 2000) proposed a new two dimensional (2D) and three dimensional (3D) chain codes, Vertex Chain Code (VCC) and Orthogonal Direction Change Chain Code (ODCCC), respectively. For 2D the chain elements are based on the number of vertices of regular cells in touched with the boundary of two-dimensional shape. The preference for this chain code is because it is part of the shape and not only the symbol. The purpose for ODCCC notation is to represent 3D shape based on chain coding. The chain code is the basis of straight-line segmentation and orthogonal direction. This chain code has many advantages over the previous one which is Freeman Chain Code (FCC). The most important is that it is based on relative direction. The other privileges can be listed as, stable in shifting, turning, mirroring movement of image, and has a normalized starting point. Bibiesca and Velarde (2001) proposed a formal language for 3D curve representation. This language is created based on the orthogonal direction change chain code. The aim of this language is to obtain some algebraic properties of chains. The function of this language results from geometrical operation for connecting polygonal paths. The Binary Chain Code for 3D curve was introduced by Bribiesca (2004). This chain code is based on the orthogonal direction change chain code. The implementation of this chain code in representing the 3D curve was represented. This chain code is also invariant under translation, rotation, and may be the normalized starting-point.

The orthogonal direction change chain code has been applied by Bribiesca (2006) for formulating a quantitative measurement of shape dissimilarity for 3D curves. This approach is applicable as a criterion for the representation and comparison of 3D curves. This chain code has been implemented for classification and generation of 3D discrete curve, by Bribiesca (2007), while the classification and generation of 3D curve are significant topics in computer graphics, image representation, and computer vision. The set of different curves congregates of open, closed, planar, angular, binary, mirror-symmetric, and random curves.

Bribiesca (2008) introduced a method for representing 3D tree objects using chain coding. To be more exact, this descriptor is based on the concept of orthogonal direction changes chain code. Therefore, it is invariant under translation and rotation and also this descriptor starts a normalised vertex via the unique path in the tree. By implementing this notation, the shapes of the trees are being preserved, and analysing the geometrical and topological properties of tree shapes is possible.

1.2.2 The Quantization and Length Estimators

Jonas and Kiryati (1997) quantitatively and qualitatively classified differrent schemes to represent digital curves in 2D and 3D. The digital curve representation schemes consist of a quantization stage followed by chain encoding. He suggested some properties for the quantization scheme, with respect to these citeria and he also compared different 3D curve quantization.

Jonas and Kiryati (1998) mentioned that the standard approach to local length estimation is to classify the Freeman chain code elements according to certain criteria, and estimate the length as a weighted sum of the number of chain elements in each class. In addition, they proposed the length estimation based on the cube quantization. Coeurjolly et al. (2001) proposed the arithmetic definition of 3D discrete lines, from this notation; they developed an algorithm for segmentation of the discrete lines. It is then used to calculate the length of a discrete curve. This discretization is also based on the Freeman chain code.

Tajine and Daurat (2003) proved that by applying the Bresenham discretization, local length estimators when the resolution trends to be zero, do trend to be the real length. This proof is also based on the Freeman chain code.

Local and global length estimators received input as chain code format. The relative direction chain code has clear advantages over the Freeman chain code and is applied in different fields. The lack of implementation of this chain code in different dimensions with suitable quantization for length estimation is emerged. Therefore, in this study, this chain code is applied in different length estimators based on the best performance quantization. The results have the same performance than the previous length estimators. The advantage of this study is the result of length estimators is no more based on the starting point and it has become invariant under translation and mirroring movement. For global length estimator for the first time length estimation and chain code extraction are obtained in just one algorithm.

1.3 Statement of the Problem

Chain code is a primitive feature in the hierarchy of pattern recognition, Bribiesca proposed a new kind of chain code for two dimensional and three dimensional shapes, but without explicit specification of the quantization method. By obtaining these chain codes based on the suitable quantization will lead to the implementation of these chain codes in length estimation.

This study delves to answer these questions:

"How to modify length estimator algorithms based on VCC and ODCCC?"
"How to achieve local length estimation for triangular and hexagonal grids based on VCC?"
"How to obtain ODCCC based on the best quantization methods?"
"How is the performance of these length estimator methods, by implementation of these chain codes in length estimator methods?"

1.4 Objectives

The objectives in this study are:

To apply quantization method to quantize thinned binary image.

(i) To develop algorithm in extracting chain code of the quantized thinned binary image.
(ii) To develop local and global length estimator of the chain code representation.
(iii) To validate and analyze the performance of the length estimators.

1.5 Scope of the Study

This study focusses on the:

(i) Two applied quantization methods are Grid intersection Quantization (GIQ) and Neighbourhood for 2D length estimator.
(ii) Voxelization (GIQ) quantization is applied for the 3D local length estimator.
(iii) Vertex chain code (VCC) which contains three grids: rectangle (VCC-R), triangle (VCC-T) and hexagonal (VCC-H) are chosen for the 2D local length estimator.
(iv) Rectangular grid of Vertex Chain Code (VCC-R) is chosen for the 2D global length estimator.
(v) Orthogonal Direction Change Chain Code (ODCCC) is chosen for the 3D local length estimator.
(vi) Freeman Chain Code is chosen to validate the performance of the length estimators.

1.6 Significance of the Study

This study belongs to the mid-level process (1.1) in digital image processing. Due to the superior characteristics of the relative direction chain code over the previous chain code schemes, it is an effective effort to implement these chain codes in image processing methods which their inputs are chain codes. Some attributes of these chain codes which are essential to employ them in estimation of the discrete length have become inquiries. In 2D, the result of implementation of the VCC in length estimators for the first time is explored not only for rectangular grids but also for rectangular and hexagonal grids. In 3D, a curve is considered then it is quantized based on the most efficient quantization method which makes the length estimation more accurate. For both 2D and 3D cases local length estimator is proposed and also 2D global length estimator algorithm.

By the implementation of this relative direction chain code, the length estimators would be independent of shifting, turning, mirroring movement of image. The global length estimators based on Freeman chain code are constructed of two kinds of algorithm. An offline algorithm extracts chain code, and another one estimates the length of digital straight segments, but by global length estimators based on the VCC, both tasks are accomplished in one algorithm.

1.7 Thesis Organization

This study is set out in this order. In Chapter 2, a brief review of three fundamental concepts, quantization, chain code, and length estimator is explained. Chapter 3 deals with the methodology applied in this thesis. Chapter 4 is the work done on the area of quantization of thinned binary images and extracting chain code. Chapter 5 considers the length estimators for 2D and 3D based on relative direction chain code. Chapter 6 focusses on the validation and analysis of the achieved results. Lastly, Chapter 7 concludes with suggestions for future works.

1.8 Thesis Contribution

In the first phase, different quantisation schemes are applied based on the different grids. The combination of Enneagon Quantization (EQ) and GIQ is considered as the efficient quantization for hexagonal grid. The enhanced algorithm for extracting chain code is proposed based on the Palvidis boundary tracing algorithm. This algorithm is implemented in Matlab. In second phase, three local length estimators are proposed by considering VCC as input. An algorithm is proposed as global length estimation for R_VCC. This algorithm detects VCC and at the same time estimates the length based on the global length estimator, Maximum-DDSs. One local length estimator for 3D is proposed based on the ODCCC. In the third phase, The Freeman chain code is extracted from thinned binary image. The local and global length estimators are implemented based on this chain code. For validation, the result achieved from relative direction chain code. The summary of contribution is shown in Table 1.1.

Table 1.1: Contribution

<table>
<tr><td rowspan="2">Category of data set</td><td colspan="5">The Length Estimator</td></tr>
<tr><td colspan="4">Two-dimensional data set</td><td>Three-dimensional data set</td></tr>
<tr><td>Category of LE</td><td colspan="3">2D Local Length Estimator</td><td>2D Global Length Estimator</td><td>3D Local Length Estimator</td></tr>
<tr><td>Validation of the length estimator</td><td colspan="3">FCC and VCC
- *Develop Matlab algorithm based on existing theory*
- *Apply established formula*</td><td>FCC
- *Develop Matlab algorithm based on existing theory*
- *Apply established formula*</td><td>FCC
Develop Matlab algorithm based on existing theory
Apply established formula</td></tr>
<tr><td>Development of Length Estimator</td><td>*New Equation (manual calculation)*</td><td>*New Equation (manual calculation)*</td><td>*New Equation (manual calculation)*</td><td>*New Algorithm (Matlab program)*</td><td>*New Equation (manual calculation)*</td></tr>
<tr><td>Scope of Chain Code</td><td>R-VCC</td><td>T-VCC</td><td>H-VCC</td><td>R-VCC</td><td>ODCCC</td></tr>
<tr><td>Techniques in Extracting of Chain code</td><td>*Boundary Tracing Algorithm (modified existing algorithm and implemented in Matlab)*</td><td colspan="2">*Manual derivation (graph paper)*</td><td>*Boundary Tracing Algorithm (modified existing algorithm and implemented in Matlab)*</td><td>*Matlab program (new program based on modified Ray Tracing Algorithm)*</td></tr>
<tr><td>Quantization Approach for Tinned Binary Image</td><td>GIQ</td><td>*EQ+ GIQ*</td><td>*GIQ*</td><td>GIQ</td><td>CQ</td></tr>
<tr><td>Pre-Processing Original Dataset</td><td colspan="4">1. Rectangle
2. Half moon
3.Ellipse
(taken from previous research in format TBI)</td><td>1. Curve 1
2. Curve 2
(taken from MIT dataset)</td></tr>
</table>