IMAGE MATCHING USING RELATIONAL GRAPH REPRESENTATION

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To my mother and father, with gratitude

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ABSTRACT

Image matching is a process to establish correspondence between primitives of two or more images that capturing a scene from different viewing position. Various image matching techniques using image features have been known in literature. Feature-based matching algorithm cannot tackle the problem of matching ambiguities easily. This study presents an image matching technique using the structural descriptions of image. Structural descriptions are consist of lines and inter-line relationship in the line-extracted image. Three conditions of inter-line relationship, namely ordering, intersection and co-linearity, were defined and derived in this study. The method involves the representation of the structural descriptions of image in relational graph and the matching between relational graphs to perform image matching. The methodology is consists of six steps: (1) input image, (2) line segment extraction from the image, (3) the interpretation and derivation of structural descriptions from the line-extracted image, (4) the construction of relational graph to represent the structural descriptions, (5) the derivation of association graph from relational graphs to perform relational graph matching, and (6) the searching of the largest maximal clique in the association graph to determine the best matching. Hence, image matching is transformed as a relational graph matching problem in this study. Experiments are carried out to evaluate the applicability of incorporating structural information into the image matching algorithm. The data is consisting of 14 pairs of stereo images. From the result obtained, it was found that the usage of structural information of image is only plausible for the matching of images of simple scene. The matching accuracy of images of complicated scene remains low even after the incorporation of inter-line descriptions into the image matching algorithm.

ABSTRAK

Pemadanan imej adalah satu proses untuk menubuhkan persamaan antara primitif daripada imej-imej yang menangkap satu pemandangan dari kedudukan pandang yang berlainan. Pelbagai teknik pemadanan imej yang menggunakan ciri imej telah diketahui dalam literatur. Pemadanan imej berasaskan ciri tidak dapat mengatasi masalah keraguan pemadanan dengan mudah. Kajian ini menyampaikan satu teknik pemadanan imej yang menggunakan maklumat struktur imej. Maklumat struktur adalah terdiri daripada garisan dan hubungan antara garisan dalam imej penyarian garisan. Tiga keadaan bagi hubungan antara garisan yang dinamakan aturan, persilangan dan *co-linearity* telah didefinisikan dan diperolehi dalam kajian ini. Kaedah ini melibatkan perwakilan maklumat struktur daripada imej dalam graf hubungan dan pemadanan graf hubungan bagi memadankan imej. Metodologi adalah terdiri daripada enam langkah: (1) kemasukan data imej, (2) penyarian segmen garisan daripada imej, (3) interpretasi dan perolehan maklumat struktur daripada imej penyarian garisan, (4) pembinaan graf hubungan untuk mewakili maklumat struktur, (5) perolehan graf gabungan daripada graf-graf hubungan untuk memadankan graf hubungan, dan (6) pencarian *maximal clique* yang terbesar dalam graf gabungan untuk menentukan pemadanan terbaik. Dengan itu, pemadanan imej telah diubah sebagai masalah pemadanan graf hubungan dalam kajian ini. Eksperimen telah dijalankan untuk menilai kesesuaian untuk mengintegrasi maklumat struktur ke dalam algoritma pemadanan imej. Data adalah terdiri daripada 14 pasang imej stereo. Daripada hasil yang diperolehi, didapati bahawa penggunaan maklumat struktur adalah munasabah hanya untuk imej yang mempunyai pemandangan yang tidak kompleks. Ketepatan pemadanan imej bagi imej yang mempunyai pemandangan kompleks tetap rendah walaupun selepas menggabungkan hubugan antara garisan ke dalam algoritma pemadanan imej.

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LIST OF SYMBOLS

A	-	Searching area
B_{lr}	-	Similarity measure
d	-	Euclidean distance
e	-	edges (arcs)
E	-	Set of edges (arcs)
G	-	Relational graph
h	-	The length of a line (in the number of pixels)
l	-	Line
l	-	Line in the left image
$l: r$	-	Left-to-right matching pair
max	-	Maximum operation
min	-	Minimum operation
m_c	-	The slope of the line under consideration
m_s	-	The searching slope
nEdge	-	The number of edges in an image
nElement	-	The number of elements in an adjacency matrix
nLine	-	The number of lines in an image
nNode	-	The number of nodes in a relational graph
nnz	-	The number of non-zero elements in an adjacency matrix
nT	-	The number of relations hold by a line
p	-	Properties
P	-	Set of properties
r	-	Line in the right image
(r_e, c_e)	-	The ending pixel of a line
(r_s, c_s)	-	The starting pixel of a line

S	-	Relational Structure
t	-	Relations
T	-	Set of relations
v	-	Elements (Nodes)
V	-	Set of elements (Set of nodes)
θ	-	The orientation of a line
ρ	-	The density of adjacency matrix of a relational graph

CHAPTER 1

INTRODUCTION

1.1 Introduction

Generally, image matching is a process of automatically establishing correspondence between primitives of two or more images that capturing at least partly the same object or scene from different viewing position. Image matching also can refer as a process to associate the content or primitives of two or more images that capturing an object or scene from different position (Julien, 1999).

Image matching can be illustrated as a process of identifying the corresponding points of two images (see Figure 1.1 and Figure 1.2) or more images, which cast by the same physical point in three-dimensional (3-D) space from different viewing position (Medioni and Nevatia, 1985).

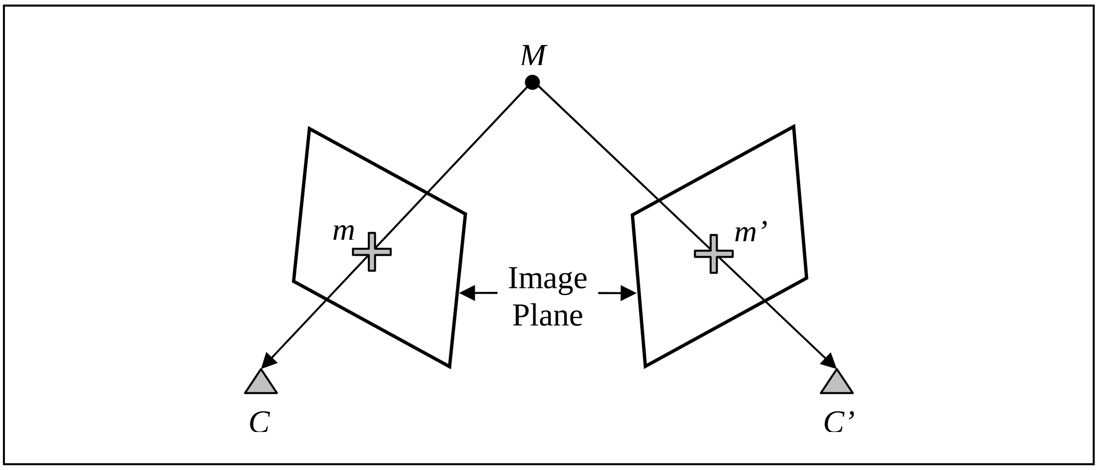

Figure 1.1: The plotting of two corresponding imaged points, *m* and *m'* in two images, cast by the same physical point *M* in 3-D space, from different viewing position, *C* and *C'*

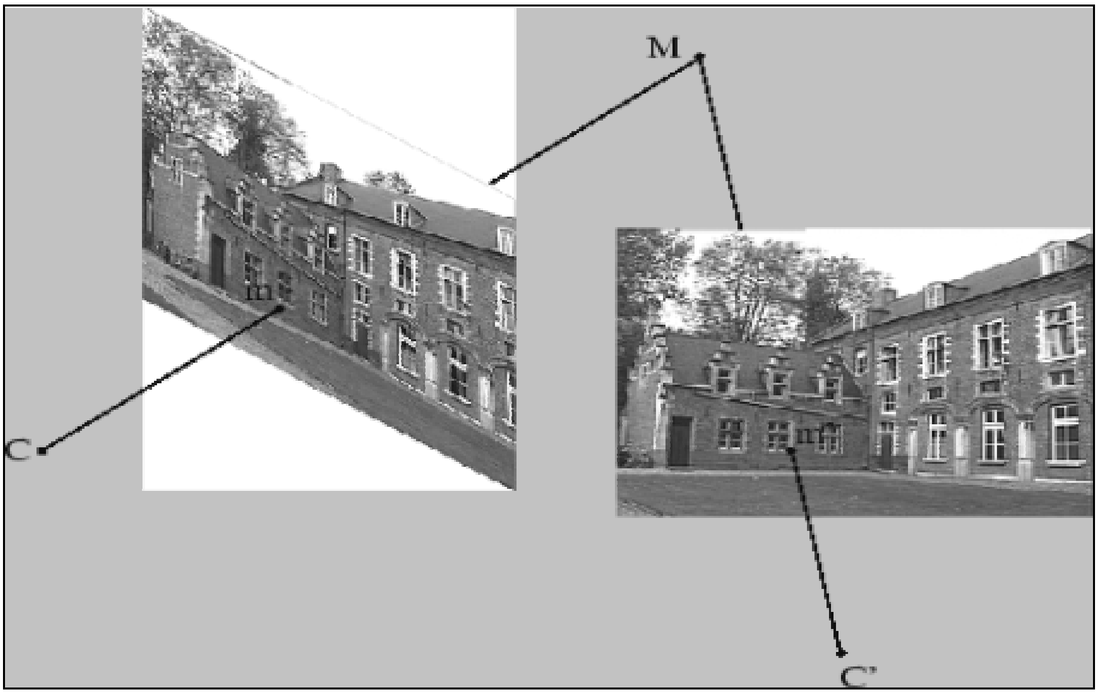

Figure 1.2: The two corresponding imaged points, *m* and *m'* in two images, cast by the same physical point *M* in real scene (3-D space), from different viewing position, *C* and *C'*

Image matching is an integral part of many computer vision tasks such as image registration, feature tracking, 3-D structure recovering from stereo images, multiple images or image sequences. For instance, the first step in recovering 3-D information of a static scene from a pair of stereo images is the matching of a set of identifiable of corresponding details between images. Where, a number of corresponding image primitives is used to match different images to each other and establish a local triangulation, to recover the depth of the scene. In addition, establish correspondence between images of a set of image sequences is also a key step in recovering 3-D structure from image sequences. Where, the correspondence is used to calculate the motion parameters of the camera with respect to the objects in the scene, to reconstruct the structure of the objects in the dynamic scene.

Over the years, a broad range of image matching techniques has been proposed for various types of data and many domains of application, resulting in a large body of research. Some interesting areas are recovering 3-D structure from stereo images or image sequence for autonomous vehicle navigation, industrial automation and augmented reality.

Approaches for image matching can be broadly classified into two categories: area-based matching and feature-based matching. Area-based matching uses intensity profiles or grey value template as the matching primitive. But, more recently, image features have extensively applied to image matching to establish image correspondence. In the feature-based approach, features are first extracted from the images, and then the matching process is based on the attributes associated with the extracted features. Feature-based matching alone might not deal with the problem of matching ambiguities easily. Some additional constraints must be imposed to control the search of matching candidates and reduce the possibility of error caused by ambiguous matching.

1.2 Problem Background

Ideally, set of corresponding details and coherent collections of pixels between images are assumed always can be determined and then provide a reliable matching between images.

Ambiguous matching might happen, if some image primitives that are visible in one image are occluded partially or totally in the other. In addition, ambiguities might arise if set of corresponding details between images are not available, in a small quantity, or incompatible. Sometimes, a local primitive in one image matches equally well with more than one primitive in the other image (known as one-to-more mapping). All these situations will lead to ambiguities in matching where a one-to-one mapping between image primitives is difficult to establish.

Image matching can be complicated by several factors related to the geometric and radiometric properties of the images. For instance, when working with stereo images that capturing over a scene from different viewing position, geometric distortion in images, variation of image attributes and scene illumination could contribute to ambiguities in the matching result (Salari and Sethi, 1990). Sometimes, periodic structures in the scene can confuse the image matching process because a feature in one image may confuse with features from nearby parts of the structure in the other image, especially if the image features generated by these structures are close together, compared with the disparity of the features (Barnard and Fischler, 1982).

In fact, these ambiguous conditions are likely to occur, when feature extraction does not provide reliable result, when image primitives are missing or partly occluded due to noise or shadow in the image, or when images are geometrically distorted due to different perspective viewpoint (Medioni and Nevatia, 1985). All these geometric or radiometric changes in images can in turn lead to wrong correspondence and causing the matching result drift away from their original correspondence set.

Therefore, in order to control the search of matching candidates and minimize the occurrence of false matching, some matching constraints should be imposed in conjunction with the matching algorithm (refer Section 2.4.2 for details). Nevertheless, the matching of images of complicated scene remains difficult even after the application of these matching constraints and strategies into the matching algorithm.

There are a number of reasons for this: (1) feature detection is not perfectly reliable, so false feature may be detected in the images, (2) feature in one image may be partially seen or fully occluded in the other image due to shadow, noise, failure in feature extraction, and thus it is difficult to find a one-to-one mapping between images, (3) one object may look different and varied in its attributes in the other images due to different viewing position and perspective distortion, and (4) ambiguities may occur, caused by repetitive pattern in the scene.

Many feature-based matching approaches have to go through some processes such as edge detection, edge linking, binarization and thinning during the feature extraction process. Feature-based image matching algorithm is relies heavily on the quality of image and the performance of feature extraction.

Thus, a method to tackle the problem is to perform image matching from feature-extracted image without relied solely on the identifiable primitives in the feature-extracted images. This means that the proposed method should not constrained much by the quality of the image, the performance of feature extraction algorithm and the quality of extracted features. It also should capable to work with two image descriptions that are not likely to have a strict one-to-one correspondence at the feature extraction level.

By considering the clarified needs, a structural-based matching technique is proposed in this study. This study involves the interpretation and derivation of structural descriptions from image, the construction of relational graph to represent the structural descriptions and the matching between relational graphs. Hence, image matching is carried out as relational graph matching in this study.

1.3 Motivations

Image matching is an important task in scene analysis and computer vision, which is to match two or more images taken.

Given two or more images, the matching of images or other closely related tasks such as image registration, pattern detection and localization, and common pattern discovery can be defined. Image registration is to find the transformation under which an image spatially fits best to another. Pattern detection and localization is to detect whether a small image is a sub-image of another image and locating the position of the sub-area. Whilst, common pattern discovery is to find the maximum common sub-image of two or more images.

Despite of that, a broad set of applications also motivate the research area of image matching. Related areas include image registration, change detection, map updating, feature tracking, stereo matching, or recovering structure from image sequences for autonomous navigation.

All these research have different level of purposes and difficulties, as a result, often associates with different approaches and solutions. They differ in their choice of primitives and the criteria used to resolve ambiguities, and each method has its own affinity function. The configuration of the method depends on the correspondence problem and the complexity of the scene. Commonly, there are constraints and schemes that can help reducing the number of false matches. From the review of previous works (refer Chapter 2), many open problems still exist in image matching.

1.4 Problem Statement

This study is devoted to interpret and derive structural descriptions from an image. This study also looks into the incorporation of structural descriptions into image matching, in the context to look for compensation for failure in feature extraction, occlusion, noise, varied image acquisition condition and dissimilarity between images or other similar problem domain occurred in the feature-extracted images. To move on to tackle with the foregoing problems, the solution should not constrained much by the quality of the image, the performance of feature extraction and the quality of extracted feature.

1.5 Objectives

The objectives of the study are:

(1) To derive the structural descriptions of an image.

(2) To represent the structural descriptions of an image using relational graph.

(3) To perform image matching based on the constructed relational graphs.

1.6 Scope

This study focuses firstly on the derivation of structural descriptions of an image. The structural descriptions of an image are defined as image features and their interrelationships in the image. Line features are extracted from a greyscale image. No pre-processing of greyscale image is done. Next was the study on the derivation of relationship between the extracted line features. The detection of inter-line relationships would be based upon the line extraction result. Nevertheless, line segment labelling would be studied, prior to the derivation of inter-line relationship. The inter-line relationships that derived for this study are confined to ordering, intersection and co-linearity.

In addition, emphasis is given to the utilization of structural descriptions of the line-extracted image in image matching. Image matching would be based on the result of the first phase of the study. Where, image matching involves the representation of the derived structural description of an image in relational graph and the relational graph matching to implement image matching.

Experiments would be run to evaluate the applicability of incorporating structural information into image matching. The data would consist of 14 pairs of stereo images. The data is confined to non-metric images, which is taken without any pre-acquisition setting.

1.7 Research Contributions

The work addressed in this study has contributed to the following aspects:

(1) An algorithm that transforms a feature-extracted image to its structural descriptions, represents the derived structural descriptions in relational graph, and performs graph matching between these relational graphs, was proposed in this study.

(2) Three conditions of inter-line relationship in the line-extracted image, namely ordering, intersection and co-linearity, were defined and derived. The applicability and limitation of these inter-line relationships were analyzed.

(3) The idea of applied relational graph matching to image matching was introduced. The incorporation of structural information of an image and the characteristics of relational graph representation in assisting image matching were studied and examined.

(4) Relational graph matching by forming an association graph structure and computing the largest maximal clique in the association graph was performed and evaluated.

1.8 Organization of the Thesis

The thesis is organized as follows: Chapter 1 is a brief introduction of the study. The background, motivation, problem statement, objectives and scopes of the study are discussed in this chapter.

Chapter 2 describes some background knowledge and reviews previous works dealing with image matching.

Chapter 3 presents the methodology and theoretical framework of this study. This chapter explains the steps of transforming the line-extracted image to its structural descriptions and representing the derived structural descriptions as a relational graph for subsequent graph matching process.

Chapter 4 reports on the implementation of the proposed approach. The methodology is designed to be implemented modularly by five computer modules, namely feature extraction module, structural description derivation module, relational graph module, association graph module and clique-finding module.

Chapter 5 presents and discusses the results of conducted experiments based on the proposed structural-based image matching technique.

Chapter 6 summarizes and concludes the study and outlines topics for future work.

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