Chapter 1

Introduction

1.1. Motivation

The original motivation for the work described in this thesis stemmed from a desire to segment underwater video images taken by remotely operated vehicles (ROVs). It was thought that the ability to interpret these images would, in conjunction with the processing of data from range sensors, enable simple vision tasks to be undertaken; such as pose determination of the cylindrical components of underwater structures. Unfortunately the sub-sea environment is an extremely hostile one in which to attempt such tasks. Back scatter from plankton and other suspended matter, marine growth, corrosion, and the fact that the majority of underwater structures are painted dark grey, mean that images are often noisy and of poor contrast. However, the different textures in the image, caused by back scatter and marine growth etc. may be exploited. Application of a texture segmentation and classification scheme [Linnett91a] to images of an underwater installation produced good results [Chantler91]. This raised the question of what would happen to the appearance of the textures when an ROV moved around a structure — as the position and orientation, of both the viewer and the vehicle mounted illumination, would change relative to the physical texture.

As the research proceeded the scope of the work was reduced to that of investigating the effects of changes in illuminant direction. Such variations may be encountered in a variety of situations. Close proximity point lighting, often used for inspection purposes, provides illumination at varying angles over the scene. Remote sensing devices sensitive to the visible spectrum experience variations in illuminant vector according to the time of day. Many other remote sensing systems that provide their own illumination, e.g. active sonar and radar, are non-stationary and hence the illuminant vector is dependent upon the approach and orientation of the survey platform. Thus there are a wide range of applications in which texture classification may have to be performed under varying illumination conditions. The work described here was therefore divorced from the original underwater application.

Thus the aims of this thesis are :

(i) to provide an understanding of the effects that variation in illuminant direction has on images of physical texture,

(ii) to investigate the impact of these effects on texture classification and segmentation, and

(iii) to propose methods of reducing classification errors caused by variation in illuminant direction.

1.2. Scope of the research

This section outlines the scope of the work described in this thesis. For reasons of brevity not all of the restrictions are described here — further details are given in the appropriate chapters.

Texture classification, as referred to in this thesis, normally involves three processes, as illustrated in figure 1.1.

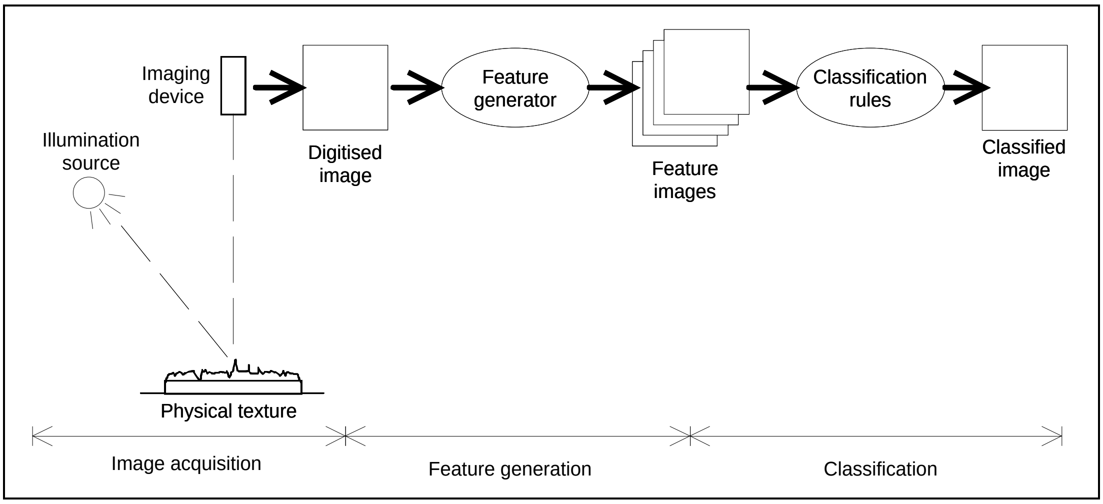

Figure 1.1 - Processes in texture classification

First, the subject texture must be illuminated and its image acquired (in the case of images taken in the visible spectrum this is normally performed using a stills camera and scanner, or alternatively a video camera and frame store). Second, feature operators are applied to the digitised image to produce a set of feature images that provide a numerical description of the characteristics of the texture(s). Third, a set of rules is applied to classify the image into texture classes.

This thesis concentrates on the effects of variations in the image acquisition process. More specifically it is concerned with the effects that changes of illuminant direction have on feature generation and classification.

Among other restrictions, the illumination is assumed to be unidirectional and the physical texture assumed to consist only of surface relief; that is it is assumed to contain only *topological texture*[1]. The experiments are confined to the variation of illuminant direction; the viewer's position being fixed vertically above the physical texture which lies upon a horizontal plane (as depicted in figure 1.1). The investigation into the effects on classification is restricted to the case where the illumination is varied between training and classification sessions.

1.3. Thesis organisation

This thesis essentially consists of two parts. The first part, comprising chapters 2 and 3, is concerned with the image acquisition process; that is it investigates the effects of variation in illuminant direction on image texture. The second part, comprising chapters 4, 5, and 6, examines the impact that these effects have on feature generation and classification, and proposes methods for reducing the resulting errors.

Hence chapter 2 provides a short review of research into the effects of illuminant variation on image texture. One model due to Kube and Pentland [Kube88] is identified and presented. Its implications for texture classification are assessed. Chapter 3

[1]The term *topological texture* is used solely to refer to the three-dimensional variation, or relief of a physical surface. In contrast the term *albedo texture* is used to refer only to *surface markings*. *Image texture* consists of intensity variations in the image plane and can be due to either topological or albedo texture or a combination of the two. However, as stated above, only the former is of direct concern here.

investigates the validity of this theoretical model using simulations and laboratory experiments.

Having investigated the effect of changes in the illumination direction on image acquisition, the second part of the thesis addresses its effect on feature generation and classification. In chapter 4 feature sets employed in texture classification are surveyed and three are selected for further investigation. Chapter 5 reports the results of this further investigation which uses images of isotropic textures captured under controlled illumination conditions. In chapter 6 these same images, augmented with images of a directional texture, are made up into montages and used to test the effects of variation in illuminant vector on three classifiers. The second half of this chapter proposes several methods for the reduction of classification errors induced by changes in illuminant tilt[2], and one proposal is implemented and tested on montages of the test textures.

Finally, in chapter 7, the work is summarised and final conclusions presented.

1.4. Original work

It is believed that this thesis contains two topics which represent original work. First, the effect of variation in illuminant direction on supervised texture classification has been explicitly investigated; and second, a compensation scheme has been developed which is shown to be capable of reducing classification errors induced by changes in illuminant tilt.

1. In chapter 5 variation of the illuminant vector is shown to affect the outputs of three sets of texture features when they were applied to images of isotropic textures, and an existing metric — the Mahalanobis distance — is adapted for use as a new measure of sensitivity to tilt variation. In chapter 6 classifiers based upon these three feature sets are shown to be adversely affected by changes in illuminant direction between training and classification sessions. While this

[2]The tilt angle of the illuminant as referred to here, is the angle that the projection of the illuminant vector onto the texture reference plane makes with an axis in that plane. Its companion, slant angle, is the angle that the illuminant vector makes with a normal to the reference plane (see figure 2.1).

behaviour seems obvious, it is believed that it has not been investigated and reported before from the perspective of automated texture classification.

2. The second half of chapter 6 is devoted to the development of a scheme that is designed to compensate for variation in illuminant tilt. This scheme comprises a set of filters derived from a frequency domain model of image texture. The model, originally due to Kube and Pentland [Kube88], was further developed in the light of empirical evidence presented in chapters 3 and 6. Application of the scheme to three classifiers reduced tilt induced errors when tested on montages of isotropic and directional textures. It is believed that this scheme represents a novel approach to illuminant tilt compensation.