Preface

Environmental Informatics studies how information can be acquired, stored, processed, modelled, and communicated for environmental sciences and management. Originated in early 1990's, Environmental Informatics has developed into a multi-disciplinary area that not only covers environment sciences and engineering, but also covers or interacts closely with information and communication technology, electronic engineering, agriculture, biology, earth sciences, remote sensing, and so on. The goal of Environmental Informatics is to foster effective collection, management, share, and use environmental data to obtain a better understanding of our changing environment, identify and manage the risk and opportunities in the interaction between natural systems, human activities and society, and ultimately maintain a sustainable relationship between the human species and nature.

One of the key tasks in Environmental Informatics is the collection and analysis of environmental data. Data collection techniques have been developing very quickly during the past decades. Apart from human field data collection, a wide range of sensors have been produced and deployed on terrestrial, airborne, spaceborne, and underwater platforms, as well as in various laboratory settings. Among them, imaging sensors have unique capability of generating 2D, 3D, or 4D snapshots of scenes. They provide human observers with comprehensive, intuitive, and easy to understand information of environmental targets. Besides widely adopted grayscale and colour images, microwave, Radar, LiDAR, multispectral, and hyperspectral images have also been adopted in environmental sensing. They provide heterogeneous information on the internal and external properties of the monitoring targets, both remotely and in close range.

Computer Vision and Pattern Recognition (CVPR) provide Environmental Informatics with powerful tools for data interpretation and analysis. Computer Vision is a discipline that understands the world through cameras and images while Pattern Recognition focuses on the detection and recognition of structures in data. These two fields come together when there is a need for image interpretation. They play important roles in the processes involved in Environmental Informatics due to their pervasive, non-destructive, effective, and efficient nature. As a consequence CVPR has made significant contributions to Environmental Informatics by enabling multi-modal data fusion and feature extraction, supporting fast and reliable object detection and classification, and mining the intrinsic relationship between different aspects of environmental data.

With the increasing amount of environment image data and requirements on developing new sensing and image interpretation techniques, CVPR has been widely studied and employed in real environmental applications including insect recognition, leaf classification, fish monitoring, wild fire detection, disaster damage estimation. CVPR researchers are working closely with environmental researchers and have jointly developed a number of successful projects which have led to large scale database and promising technology. An example is the hand-held electronic field guide developed by researchers in Columbia University and University of Maryland. This project aims to compare leaf snapshots to a library of leaf images[1]. A team led by Professor Thomas G. Dietterich in Oregon State University has undertaken several projects in ecosystem informatics and computational sustainability[2]. In these projects, CVPR approaches have been developed and applied to predict species distribution, predicting bird migration patterns and identify small anthropods. Another successful story comes from collaboration between CVPR and environmental researchers in Europe and Asia. The Fish4Knowledge project[3] uses video cameras to observe and analyse the presence and behaviour of undersea animals. This project has covered the several key components in developing a usable environmental monitoring system, including information abstraction and storage, automatics information retrieval, robustness to noisy environment, and a user friendly interface for the integration of human knowledge and machine intelligence.

The big data nature of Environmental Informatics and the complex environmental monitoring and analysis practice have boosted fundamental research in CVPR. A number of computer vision tasks such as image denoising, feature extraction, feature description, 3D modelling, image retrieval and matching, object and image classification, have been cast into real environmental data interpretation challenges which require high robustness, effectiveness, and efficiency. From a pattern recognition point of view, statistical, structural, and syntactic approaches have all be investigated and extended for the need of detection, recognition, and prediction. The development on these topics has nurtured the creation of new workshops, building of interest groups, and publication in major CVPR venues, such as IEEE International Conference on Computer Vision, IEEE Conference on Computer Vision and Pattern Recognition, IEEE International Conference on Image Processing, and International Conference on Pattern Recognition.

The objective of this book is to present the latest progresses on the multidisciplinary research field that includes CVPR as part of Environmental Informatics. We have gathered high-quality contributions that reach beyond the state-of-the-art. These include examples of environmental image acquisition and matching, feature extraction, object detection and recognition, tracking and 3D modelling where computer vision methods play an indispensible role. This book also presents discussions to innovate new ideas and problems in applying CVPR to environmental applications. In doing so, we attempt to provide useful references for professionals, researchers, engineers and students with various backgrounds and within different communities.

This book is organized into three sections, focusing on underwater life, insect, plant and soil, respectively. Following is a summary on each section and their corresponding chapters.

SECTION 1: COMPUTER VISION AND PATTERN RECOGNITION METHODS FOR AQUATIC ANIMAL DETECTION AND MONITORING

As the section title stated, this section focuses on the applications of CVPR methods for detecting and monitoring of animals living in an aquatic ecosystem. Aquatic ecosystems include both marine and freshwater ecosystems. They perform many key environmental functions and produce significant primary production. Monitoring aquatic ecosystems is highly important for detecting environmental changes and facilitating industrial production. This can be achieved through aquatic life analysis, and in particular, monitoring and recognition of underwater animals. However, this is a very challenging task due to complex underwater environment, limited illumination, and diversity of aquatic species. This chapter contains six chapters dedicated to solve different aspects of the problems.

Chapter 1 introduces a hierarchical decomposition method to detect unusual fish trajectory from videos captured from underwater environment. This is one of the tasks for fish behaviour understanding which provides clues to detect changes of their living environment. In this chapter, usual fish trajectory is defined as those that are different from common behaviour of fish. To facilitate the classification, labelled and clustered data are used to train a classifier. Those behaviours that fell into small clusters are considered as usual trajectory or outliers. During the clustering and outlier detection step, feature selection is performed with the help of the labelled data so that best trajectory features can be selected. The optimal combination of features and trajectory segments form the final hierarchy for detection. The authors of this chapter compared their method with the state-of-the-art unsupervised approaches and show that it generates superior detection rate.

Chapter 2 describes a machine learning method to automatically detect scallops using an autonomous underwater vehicle system. This method is built on a recently developed approach which has three steps. The first step adopts a top-down visual attention model to detect regions that may contain scallops. Then the regions are selectively segmented to extract boundaries of candidate scallops and get a circle shape fitted to the boundaries. In the third step, shape and orientation profiles of the region in each circle is fed into a trained classifier for scallop detection. The problem of this classification system is that many regions that do not contain scallop are positively classified. In order to reduce the false positives, authors evaluated two possible solutions, i.e., weighted correlation template matching and histogram of gradients. The experimental results show that the former is a better option.

Different from the first two chapters in which images or videos are taken by one camera, in chapter 3, authors introduce a system equipped with a pair of cameras to capture stereo under water video footage. This allows three dimensional information of fish be reconstructed for fish counting and measurement. Yet, the challenge lies in how to develop a fast and reliable system. The authors propose that this can be solved by breaking the task into three major steps, i.e., identification, tracking, and measurement. A series of image processing and pattern recognition approaches are adopted in these three steps, including background subtraction, filtering, template matching, and shape fitting. In this chapter, authors also give a comprehensive review on fish detection and counting method, and suggest using supervised learning approach to improve the accuracy of the identification accuracy.

In chapter 4, Varun Santhaseelan and Vijayan K. Asari introduce a unique and interesting application of CVPR on automated whale blow detection in infrared videos. Its value is obvious: providing an assistive technology to release whale researchers from tedious visual observation and whale detection from videos. Three solutions are proposed for this purpose. The first solution is based on a multi-layer perceptron, which is effective but misses some small whale blows. The second solution uses local relative variance and fractal features. It can solve the problem of multi-layer perceptron with the cost of increasing false positive detection. The last solution is based on one of the latest deep learning methods, the convolutional neural networks, which has generated the best performance.

Chapter 5 is titled “Automatic fish segmentation and recognition for trawl-based cameras”. The technology in this chapter is developed for fish abundance estimation from low contrast video data. The reported video acquisition system contains cameras, LED strobes, supporting hardware, and image acquisition software. For automatic fish segmentation, statistics of image regions are calculated and used for object boundary detection. The output is then used for fish recognition. A class hierarchy of fish is learned by unsupervised approaches. During the process, a partial classification mechanism is introduced so as to allow partial discriminative features be utilized in the classifier learning process. The proposed system has generated 93% recognition rate on mid-water image sets.

The last chapter in this section focuses on box jellyfish movement tracking. Box jellyfish has a unique visual system which has high value in studying the roles of vision in early stages of eye evolution. To understand how this visual system is linked to the movement of box jellyfish, it is necessary to track and analyse such movement. As pointed out by the authors, this is a non-trivial problem due to the differences on image quality. Similar to the solution in chapter 3, the method in this chapter also adopts a detection and then tracking framework. An important feature used to facilitate detection and tracking is the rhopalia which are disc shape structure in the box jellyfish. They form the targets of tracking instead of the actual body of jellyfish.

SECTION 2: COMPUTER VISION AND PATTERN RECOGNITION METHODS FOR INSECT RECOGNITION AND MODELLING

Insects are the most diverse animal life forms on earth, with estimated number of species to be millions. This makes insect recognition a very challenging task. The recognition and modelling problem is further complicated by normally small size of insects, and slight differences between species. The CVPR research in this area is promoted by the building of large scale insects databases, such as the Atlas of Living Australia[4]. The need also comes from the emerging demand in biosecurity, agriculture, environment protection, and tourism. This section contains four chapters, with topics ranging from feature extraction, 3D modelling, to recognition, aiming to tackle the challenges mentioned previously.

Chapter 7 is about insect recognition using sparse coding and decision fusion. In order to classify insect images, a common practice is to convert images into vectorized representations so that they can be used as input to classifiers. Coding and pooling are two key steps to construct such representation. In this chapter, authors implemented three main stream coding methods including hard coding, soft coding, sparse coding, and salient coding. The authors discover the most discriminative codes among these four options, and used them for the next pooling process. At the classification level, decision fusion method is used to generate more robust prediction model. The proposed approach was applied to a fruit fly dataset with about 20 species whose images are captured at different views. The experimental results show that this method is very effective and efficient.

Chapter 8 studies feature extraction from butterflies. Feature extraction is one of the most important steps in a CVPR system. Extracting simple yet discriminative features determines the accuracy of insect classification. The idea in this chapter is to compute skeletal curve of shapes from natural objects contained in environmental images. In this chapter, images are first converted into binary form, so that edges can be extracted. These edges are linked into contour whose shape is optimized through mathematical modelling. This leads to skeleton feature representation that is robust to noises in the image, or complex structure of binarized object shape.

The title of chapter 9 is "Categorization of Plant and Insect Species via Shape Analysis". Similar to chapter 8, this method also rely on contours of insects or plants for specie classification. When object contours have been generated, authors propose to construct a graph using contour points as the vertices of graph. Then the distance between each pair of vertices are calculated. The distribution of such distance is used to build a histogram representing the frequency of normalized distances. The histograms are further processed using a classic bag-of-words model, so as to produce a vectorized form of each contour image. Then classifier can be trained to predict the species of insects or leaves. The shape information is further combined with hierarchical local structural information to build better recognition system.