3-D Surface Geometry and Reconstruction: Developing Concepts and Applications

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Chapter 1
Methods of 3D Object Shape Acquisition ......................................................... 1
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This chapter describes the methods for acquisition of 3D data from surface as well as internal structure of the existing objects. The acquisition methods of interest are optical methods based on objects surface image processing and CT/NMR sensors that explore the object volume structure. The focus is on 3D surface shape acquisition methods based on multiple views, methods using single view video sequences, and methods that use a single view with a controlled light source. A set of algorithms suitable for the acquired 3D data processing and simplification are shown to demonstrate how the models data can be processed.

Chapter 2
Projective Geometry for 3D Modeling of Objects.............................................. 28
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This chapter discusses the basic elements of projective geometry that are needed to reconstruct objects in 3D space. In particular, it discusses the role of this branch of geometry in reconstructing basic entities (e.g. 3D points, 3D lines and planes) in 3D space from multiple images. It investigates the geometrical relationships when one or two cameras are observing the scene creating single-view and two-view geometry. Finally, different approaches to deal with the existence of noise or inaccuracy in general are presented.
Chapter 3
PDE-Based Image Processing: Image Restoration

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This chapter explains partial differential equation (PDE) based approaches for image modelling and processing for image restoration task. The general basic concepts of partial differential equation based image modelling and processing techniques are discussed. As a case study, the topic in consideration is oriented towards image restoration using PDEs formalism since image restoration is considered to be an important pre-processing task for 3D surface geometry and reconstruction and many other applications. An image may be subjected to various types of noises during its acquisition leading to degraded quality of the image. Here, the PDE-based models for removal of these noises are discussed.

Section 2
3D Reconstruction

Chapter 4
Hybrid GPU Local Delaunay Triangulation through Points Consolidation

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This chapter presents a hybrid reconstruction method by combining interpolating and approximating features together in order to be implemented efficiently in parallel architectures. Hybrid methods are useful in areas such sculpting, medicine, and cultural heritage, where details must be preserved. The proposed method makes use of a point projection operator to create a regular distributed and noise free set of points, which is reconstructed using local Delaunay triangulations. Both points projection and triangulation methods are studied in its the basic serial version, but aiming to design parallel versions (more specifically GPU implementations) that increase their performance. The adaptations required for the parallel reconstruction are discussed, as well as and several implementation details are given.

Chapter 5
3D Reconstruction of Underwater Natural Scenes and Objects Using Stereo Vision

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3D reconstruction for underwater applications is a relatively recent research area with higher complexity than the 3D reconstruction for general applications. 3D reconstruction of underwater natural scenes and objects is a challenging problem due to light propagation in underwater. In contrast to light propagation in the air, the light rays are attenuated and scattered, having a great effect on image quality. This chapter proposes a preprocessing technique to enhance degraded underwater images as well as a stereo vision based 3D reconstruction technique to reconstruct 3D surface of underwater objects. The developed reconstruction technique is expected to be robust enough to reconstruct objects or scenes in a realistic manner. The system is robust, which means that it should be able to reconstruct the object or scene which that is far away and captured in turbid water.
Chapter 6
3D Reconstruction of Graph Objects, Scenes, and Environments......................................................... 137
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This chapter focuses on the theoretical background, pedagogical practice, usability, and applicability of using 3D surface charts. It seeks to discuss the importance of surface objects, scenes, and environments reconstructed to enhance the interpretation of charts. Different types of 3D charts available: bar, line, and pie charts are described. The chapter also provides enlightenment about two new concepts i.e. “3D actual” and “3D obvious” charts. Indeed, the visual communication theory provides a relevant framework from which educators can design and develop a tool to aid learners who need visually representative data via charts, graphs, and pictures to enhance learning.

Chapter 7
Depth Estimation for HDR Images........................................................................................................... 165
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This chapter introduces a stereo matching algorithm that analyses grayscale or color images to estimate the disparity map for 3D scene reconstruction. The proposed algorithm consists of two major techniques namely conversion of High Dynamic Range (HDR) images to Low Dynamic Range (LDR) images or Standard Dynamic Range (SDR) images and estimating the depth from the converted LDR / SDR stereo images. Local based tone mapping technique is used for the conversion of the HDR images to SDR images. Depth estimation is done based on the corner features of the stereo pair images and block matching algorithm.

Chapter 8
Monocular-Cues Based 3-D Reconstruction: A Comparative Review .......................................................... 181
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In recent years, some interesting breakthroughs have been made in constructing depth maps of images using monocular cues. This chapter provides a brief review on 3D reconstruction, with a particular emphasis on monocular-cues based reconstruction. Two recent 3D reconstruction techniques that use machine-learning algorithms trained by monocular cues are explained. The success of these algorithms is their ability to not only use local features of image regions but also their global context in relation to the entire image. The fusion approach improves the 3-D estimation accuracy significantly as compared to the original approaches.
Chapter 9
Image Based 3D Modeling and Rendering from Single View Perspective Images

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In computer vision, 3D modeling refers to the process of developing 3D representation of the real world objects with systematic procedure. The 3D models can be built based on geometric information about the object or scene to be modeled using CAD/CAM software. This chapter addresses a method to construct 3D wireframes from single view perspective image based on edge length. A method for rectifying the perspective distortion has been discussed. An application of touring into picture has also been explained.

Section 3
Real-World Applications

Chapter 10
Surface Modelling Using Discrete Basis Functions for Real-Time Automatic Inspection

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The chapter focuses on the applications of discrete basis functions in surface modelling and automatic inspection. Emphasis is placed on a formal and stringent mathematical background, which enables an analytical a-priori estimation of the performance of the methods for specific applications. A completely new approach to synthesizing constrained basis functions is presented. The resulting constrained basis functions form a unitary matrix, i.e. are optimal with respect to numerical error propagation and have many applications, e.g. as admissible functions in Galerkin methods for solution of boundary value and initial value problems. A number of case studies are presented, which show the applicability of the methods in real applications.

Chapter 11
Application of Red, Green, and Blue Color Channels in 3D Shape Measurement

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Optical full-field measurement techniques have been widely studied in academia and applied to many actual fields of automated inspection, reverse engineering, cosmetic surgery, and so on. This chapter presents the application of red, green, and blue channels as a carrier in measuring 3D shape of objects surface. Since three fringe patterns can be simultaneously projected and captured through a single composite RGB image, the acquisition time reduces to 1/3 of the value by the gray fringe pattern projection. Two kinds of application methods of red, green, and blue as a carrier are discussed. The testing results confirm that red, green, and blue channels can be used as a carrier to reduce the acquisition time.

Chapter 12
Widely-Separated Stereo Views Turn into 3D Objects: An Application

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This chapter describes different steps proposed to perform scene modelling through wide baseline set of images. The camera parameters are assumed to be known approximately within some range according to the error margins of the sensors used such as inertial devices. The proposed technique is based on detecting junctions in all images using the so-called JUDOCA operator and through homographic
transformation; correlation is applied to achieve point correspondences. The match set is triangulated to obtain a set of 3D points, and point clustering is then performed to achieve a bounding box for each obstacle, which may be used for localization purposes by itself. Finally, a voxelization scheme is applied to determine a volumetric representation for each obstacle.

**Chapter 13**  
**Complementary Part Detection and Reassembly of 3D Fragments** ................................................................. 314  
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*Phalguni Gupta, Indian Institute of Technology Kanpur, India*

This chapter has explored a problem for determining the complementary part of a fragment of an object and of reassembling them to form the object. It has proposed an efficient surface inspection algorithm which detects the corresponding cleavage sites of fragments and registers them so that the object can be formed from the given fragments. For a given 3D scanned image of broken objects, the algorithm identifies the rough sites of the broken object, transforms the object to a suitable alignment, registers it with its complementary part, which belongs to the same object, and finds the local correspondence among the fragmented parts. The algorithm is found to be very effective on objects of ceramic material and archeological artifacts.

**Chapter 14**  
**3D Surface Reconstruction from Multiviews for Prosthetic Design** ................................................................. 338  
*Nasrul Humaimi Bin Mahmood, Universiti Teknologi Malaysia, Malaysia*

Existing methods that use a fringe projection technique for prosthetic designs produce good results for the trunk and lower limbs; however, the devices used for this purpose are expensive. This chapter suggests an alternative approach to design prosthetic devices using multiviews reconstruction method and offers a significant advance for orthotic as well as prosthetic design by using an image processing technique. The design and evaluation methodology, consisting of a number of techniques suitable for prosthetic design, is developed. The 3D model is obtained by a computer program, while the 3D data uses the shape-from-silhouette technique in an approximately circular motion. The methodology developed is shown to be useful for prosthetic designers as an alternative to manual impression during the design.

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