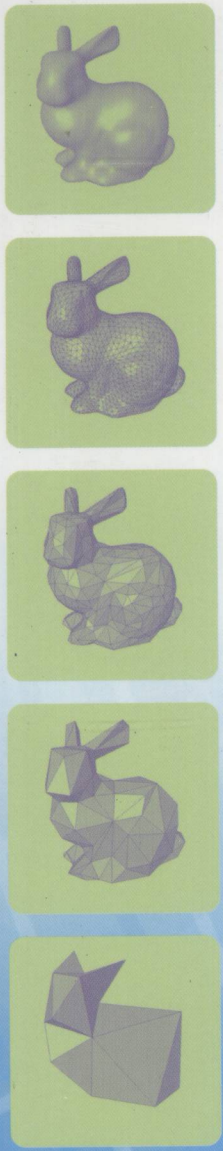

3D Object Processing

Compression, Indexing and Watermarking

Edited by

Jean-Luc Dugelay

Atilla Baskurt

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John Wiley & Sons Canada Ltd, 6045 Freemont Blvd, Mississauga, Ontario, L5R 4J3, Canada

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Library of Congress Cataloging-in-Publication Data

3D object processing : compression, indexing, and watermarking / edited by Jean-Luc Dugelay, Atilla Baskurt, Mohamed Daoudi.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-06542-6 (cloth)
1. Image processing – Digital techniques. 2. Three-dimensional imaging. 3. Digital images – Watermarking. 4. Image compression. I. Dugelay, Jean-Luc. II. Baskurt, Atilla, 1960- III. Daoudi, Mohamed, Ph. D.
TA1637.A144 2008
621.36′7 – dc22

2008003728

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-0-470-06542-6 (HB)

Typeset in 10.5/13 Times by Laserwords Private Limited, Chennai, India
Printed and bound in Great Britain by TJ International, Padstow, Cornwall

3D Object Processing

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Contents

Introduction

Scientific and technological advances in the fields of image processing, telecommunications and computer graphics during the last decade have contributed to the emergence of new multimedia, especially three-dimensional (3D) digital data. Nowadays, the processing, transmission and visualization of 3D objects are a part of possible and realistic functionalities over the Internet. Confirmed 3D processing techniques exist and a large scientific community works hard on open problems and new challenges, including progressive transmission, fast access to huge 3D databases or content security management.

The emergence of 3D media is also directly related to the emergence of the 3D acquisition technologies. Indeed, recent advances in 3D scanner acquisition and 3D graphics rendering technologies boost the creation of 3D model archives for several application domains. These include archaeology, cultural heritage, computer-assisted design (CAD), medicine, 3D face recognition, videogames or bioinformatics.

Finally, this growing 3D activity is possible thanks to the development of hardware and software for both professionals (especially 3D modeling and tools for creation and manipulation) and for end-users (3D graphic accelerated hardware, Web3D, high-quality PDAs (Personal Data Assistants), new generation of cellular/mobile phones to visualize 3D models interactively).

Why is our Community Particularly interested in these New Media?

A 3D object is more complex to handle than other multimedia data, such as audio signals, images or videos. Indeed, only a unique and simple two-dimensional (2D) grid representation is associated to a 2D image. All the

3D Object Processing: Compression, Indexing and Watermarking J.-L. Dugelay, A. Baskurt & M. Daoudi

2D acquisition devices generate this same representation (digital cameras, scanners or 2D medical systems). In consequence, any image processing function can be applied directly to all these images issuing from different sensors. This does not mean that the function will lead to satisfactory results for a universal heterogeneous 2D database; this function has to be adapted to the characteristics of different classes of 2D images, for instance.

Unfortunately (for the users) and fortunately (for the scientists), there exist different 3D representations for a 3D object. An object can be represented on a 3D grid like a digital image, or in 3D Euclidean space. In the latter case, the object can be expressed by a single equation (like algebraic implicit surfaces), by a set of facets representing its boundary surface or by a set of mathematical surfaces. The reader can easily imagine the numerous open problems related to these different representations.

The sources generating 3D data will not produce the same 3D representation for the same object. Furthermore, the different application domains have their usual types of representation. Either one needs to have a universal processing function which works with all the representations (this is inconceivable), or one needs to know how to transform a representation to the other one: this is quite complex and often constitutes open problems.

The Focus of the Book

For this book, we deliberately limit our ambition and focus on three important and complementary topics concerning 3D data: compression, indexing and retrieval, and watermarking. This choice also defines clearly the scenario of services and uses we consider: namely, *secure transmission, sharing and finding of similar 3D objects on networks*. All the four chapters are written with this scenario in mind.

Whatever the problem to resolve (compression to guarantee a rate/distortion/channel capacity constraint on networks; indexing to facilitate 3D retrieval; watermarking for copyright protection and content security and integrity improvement), we need to manipulate the same 3D representation models commonly used in computer graphics and 3D modeling. This is why it seemed very important to us to detail these models in the first chapter of this book. Before going on to the functional sections (compression, indexing or watermarking), the reader needs to visit this theoretical introduction in order to understand the characteristics, advantages and limitations of the

3D representation schemes presented in three categories: polygonal meshes, surface-based models (parametric, implicit and subdivision surfaces) and volumetric models (primitive based (superquadric, hyperquadric), voxel representation, CSG).

Chapter 2 presents the 3D coding/decoding schemes based on the different categories of 3D representation models previously presented in Chapter 1. These schemes correspond to efficient tools to reduce the size of the 3D data and the transmission time for low-bandwidth applications while minimizing the whole distortion and preserving the psychovisual quality of the 3D objects. Whatever the scheme, two main parts constitute challenging open problems: finding a concise/synthetic representation of the 3D model, even if it implies some loss of precision or some errors regarding the original object; and detecting and removing the redundancy of this model. This chapter presents two classes of schemes: those based on the well-known 3D representation, the polygonal meshes; and those which are based on new representation models instead of classical polygonal meshes (especially, more compact models like NURBS, implicit surface or subdivision surface).

Chapter 3 is devoted to the indexing and retrieval of 3D shapes: how to access and exploit 3D digital collections using visual information as queries. In recent years, many content-based image retrieval (CBIR) systems have been proposed in the literature for 2D images and videos. However, when the information is intrinsically 3D, as in computed-assisted design, a simple generalization of existing CBIR from 2D to 3D is inconceivable. One needs to reconsider the problem from scratch. This chapter presents the very recent 3D techniques for indexing, comparing and retrieving 3D objects. The approaches can be classified into three classes: view-based approaches (inspired from human perception of 3D structures that is based mainly on 2D profiles), structural approaches (based on topological descriptions of 3D shapes using for example skeleton or a set of elementary geometric objects) and full-3D approaches (based on features computed directly on a 3D space).

Finally, Chapter 4 presents the 3D watermarking methods. The past decade has seen the emergence of 3D media in the industrial, medical and entertainment domains. Therefore, the intellectual property protection and authentication problems of these media have attracted more attention in these years. It has to be noted that the community has just begun to work on this very challenging topic. The techniques are not as abundant and ripe as is the case

for other media such as images, audio and video. They have to be tested in terms of robustness on large 3D databases in order to be validated by the whole community. This chapter presents the ones with the most potential for hiding information in a 3D object without altering the visual quality and for recovering this information at any time, even if the 3D object was altered by one or more non-destructive attacks, either malicious or not.

Without further ado, we invite the reader to explore and enjoy this book.

1

Basic Background in 3D Object Processing

Guillaume Lavoué

1.1 3D Representation and Models

This chapter details the different 3D representation models, commonly used in computer graphics and 3D modeling. We distinguish three main representation schemes: polygonal meshes; surface-based models, such as parametric, implicit and subdivision surfaces; and volumetric models including primitive-based models (superquadric, hyperquadric), voxel representation and constructive solid geometry. For each of these 3D representation schemes, we analyze the advantages and drawbacks in terms of modeling, regarding different applications.

The point-based representation, which has been recently introduced in computer graphics, is not within the scope of this book. Recent reviews can be found in Kobbelt and Botsch (2004) and Alexa *et al.* (2004).

1.1.1 Basic Notions of 3D Object Representation

Now 3D objects are more complex to handle than other multimedia data, such as audio signals or 2D images, since there exist many different representations for such objects.

3D Object Processing: Compression, Indexing and Watermarking J.-L. Dugelay, A. Baskurt & M. Daoudi