Content Based Retrieval for Non-Rigid 3D Objects

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By

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Abstract

Recently, 3D objects are used in different fields such as game industry, Computer Aided Design (CAD), medicine, cultural heritage, etc. The continuous increase of 3D objects databases' size has made a necessity for the construction of efficient retrieval algorithms.

Retrieval algorithms can be driven by using textual description to the desired model. In this case, the user would explicitly describe the target. But such an approach is sensitive to the user's subjectivity factor which is not necessarily in agreement with the textual information annotated to the target. The problem of textual retrieval is that, it is based on human indexing or description of the models which differs from one person to anther and also it is time consuming. So the best way to retrieve the model, is to let the model describes itself using content based retrieval algorithms.

Content based retrieval algorithms are algorithms that use the 3D object characteristics themselves as descriptors (shape descriptors) in order to be used in the matching operation.

In the last few years, the problem of 3D object retrieval has become an active research topic and attracted more and more researchers from several research communities, including pattern recognition, computer graphics, computer vision, and applied mathematics, trying to extract discriminative descriptor.

The 3D shape retrieval can be categorized into two categories. The first category is rigid object retrieval which identifies rigid objects such as glasses, tables, building, standing humans and setting humans. Rigid considers each pose for human as separate class or category. The second category is non-rigid object retrieval which interested in articulated models. Non-rigid object retrieval concerns the human as single class whatever its pose.

The problem of 3D non-rigid object retrieval is very complex due to; the different representation of 3D models, the difference in measures of 3D retrieval performance and the different benchmarks used to evaluate the performance.

In this thesis we introduced an efficient algorithm for non-rigid 3D object retrieval. This algorithm is a view based algorithm which depends on rendering the model as range images from multiple view directions about the model, as in the Light Field Descriptor (LFD) [1]. In this thesis a new proposed method (Enhanced ray tracing) was introduced [2] and used for depth image generation. To extract local features from each range image, the proposed method uses the Scale Invariant Feature Transform (SIFT) algorithm proposed by Lowe [3]. As each depth image yields a few dozen of features, and there are a few dozen of range images per model, a 3D model is associated with hundreds of local features. Computing dissimilarity between two sets of local features having thousands or hundreds of local features each can be quite expensive. Our proposed method avoids the costly pair-wise distance computation by integrating all the local features of the model into a single feature vector by using the Bag-Of-Features (BoF) [4] approach. In our proposed method, vector-quantized local features, or visual words, from multiple range images are accumulated into single histogram to become a feature vector for the 3D model. The Modified Extremely Randomized Clustering Trees (MERC- Trees) are trained using training sample which is a subset of the whole dataset descriptors. The codebook for the vector quantization is learned via MERC of local features extracted from the 3D models in the database. The MERC splits its nodes after (T_r) of tries to get the split threshold with maximum score which makes the split more accurate and increase the classification power. The MERC leaves are labeled by the class frequencies.

From our experimental results we find that the proposed algorithm is fast to compute, compact to store and effective for retrieving non-rigid 3D objects. It achieved efficient retrieval performance on

SHREC 2011 dataset, SHREC 2015 and SHREC 2011-Robust; the public well known benchmarks of non-rigid 3D models. The results have indeed confirmed that, the proposed descriptor is invariant against different kinds of deformations. Moreover, the proposed algorithm achieved the 6th best performance on SHERC'15. keeping in mind that all participating algorithms are not view based approach and based on using the topological and geometrical features which can discriminate the non-rigid models easier than the view based algorithm.

In conclusion, the contribution of our work is introducing a compact, easy to compute and discriminative silent local visual features with SIFT feature descriptor which extracted from set of different depth images which were taken from different angles using our enhanced ray tracing algorithm [2]. Those images produce a set of few hundreds of SIFT features, Computing dissimilarity between two sets of local features having hundreds of local features can be quite expensive so, BoF approach was applied using our proposed MERC-Trees method for reducing time and space complexity.

Table of Contents

List of abbreviations

SIFT: Scale Invariant Feature Transform

SHREC: Shape Retrieval Contest

HKS: Heat Kernel Signature

MRGs: Multi-resolutionalReeb Graphs

GH: GromovHausdorff

Enhanced RT: Enhanced Ray Tracing

LFD: light field descriptor

BoF: Bag of Features

CSG: Constructive Solid Geometry

PSB: Princeton Shape benchmark

OFF: Objective File Format

PCA: Principle Component Analysis

NN: Nearest Neighbor

FT: First Tier

ST: Second Tier

R: Recall

P: Precision

DCG: Discounted Cumulative Gain

PSO: Particle Swam Optimization

GSA: Gravitational Search Algorithm

CFO: Central Force Optimization

UCI: University of California, Irvine

KM-GSA: K-means combined with GSA

PSO-GSA: PSO combined with GSA

CFO- GSA: CFO combined with GSA

KM-PSO: K-means combined with PSO

CPU: Central processing Unit

Cancer: Breast Cancer Wisconsin

CMC: Contraceptive Method Choice

BF-SSIFT: salient local visual features for 3D retrieval using bag of visual features

BF-DSIFT:dense sampling and fast encoding for 3D model retrieval using bag of visual features

BoF: Bag of features

DoG:difference-of-Gaussian function

BoW: Bag of words

PRNS: pseudo-random number sequences

QRNS: Quasi-Random Number Sequence

N_v : Number of visual words in the codebook

ERC Trees: Extremely Randomized Clustering Trees

Enhanced RT: Enhanced Ray Tracing