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Information technology — Multimedia content description interface —

Part 8: **Extraction and use of MPEG-7 descriptions**

AMENDMENT 2: Extraction and use of MPEG-7 perceptual 3D shape descriptor

Technologies de l'information — Interface de description du contenu multimédia —

Partie 8: Extraction et utilisation des descriptions MPEG-7

AMENDEMENT 2: Extraction et emploi du descripteur de forme 3D perceptuel MPEG-7

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Foreword

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Amendment 2 to ISO/IEC TR 15938-8:2002 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

NOTE This document preserves the sectioning of ISO/IEC TR 15938-8:2002 and its amendments. The text and figures given below are currently being considered as additions and/or modifications to those corresponding sections in ISO/IEC TR 15938-8:2002 and its amendments.

Information technology — Multimedia content description interface —

Part 8:
Extraction and use of MPEG-7 descriptions

AMENDMENT 2: Extraction and use of MPEG-7 perceptual 3D shape descriptor

Add after 2.2.2.49:

2.2.2.50 Attributed Relational Graph (ARG)

A graph whose nodes (vertices) and edges (links) contain unary attributes and dyadic attributes (describing the relation between the nodes), respectively. The graph is described in the form of a vector.

2.2.2.51 Constrained Morphological Decomposition (CMD)

An algorithm, based on the mathematical concepts of morphology and convexity, to decompose a voxelized 3-D object into several parts.

2.2.2.52 Weighted Convexity (WC)

A volume-weighted sum of each part's convexity.

2.2.2.53 Weighted Convexity Difference (WCD)

A difference of two WCs before and after merging of two parts.

2.2.2.54 Initial Decomposition Stage (IDS)

The procedure of applying the CMD to a voxelized 3-D object, once.

2.2.2.55 Recursive Decomposition Stage (RDS)

The procedure of applying the CMD recursively to the result of the IDS or a previous RDS.

2.2.2.56 Iterative Merging Stage (IMS)

The procedure of merging parts in the result of the RDS iteratively using the WCD.

2.2.2.57 Earth Mover's Distance (EMD)

A kind of distance measure based on a solution [AMD2-2] to the transportation problem in graph theory.

2.2.2.58 Query by Example

A query to a content (e.g. image, 3D object, etc.) retrieval system whereby the information need is expressed visually, by providing an example of the kind of target content desired. This can be useful when the user has difficulty forming a query using key words or when text descriptions are not present in the database. For example if the user wants to find images of beaches, he/she can use any available image of a beach as the query and the retrieval system is expected to return images of beaches as results.

2.2.2.59 Query by Sketch

A query by example whereby the example content is a sketch, drawn by the user, reflecting the key visual attributes of the information need.

2.2.2.60 Query by Modified Example

A query by example whereby the example content is created by modifying an existing example (for example, using a graphical editing tool) so that it best expresses the information need.

Add after subclause 8.5:

8.6 Perceptual 3D shape

The Perceptual 3D Shape descriptor is a part-based representation of a 3D object expressed as a graph. In this context “node” is a vertex in the graph representation corresponding to a part in the 3D model. Such a representation facilitates object description consistent with human perception. The Perceptual 3D Shape descriptor supports ‘Query by example’. Furthermore, it provides unique functionalities, such as ‘Query by sketch’ and ‘Query by modified example’, which make the content-based retrieval system more interactive and intuitive in querying and retrieving similar 3D objects.

8.6.1 Part-based representation

Part-based representation of 3D objects enables perceptual recognition that is robust in the presence of rotation, translation, deformation, deletion, and inhomogeneous scaling of a 3D object. More specifically, deletion and inhomogeneous scaling involve the removal of parts and growth or shrinkage of the specific part, respectively. In the task of forming a high-level object representation from low-level object features, parts serve as an intermediate representation.

The decomposition scheme [AMD2-1] is used to generate the attributed relational graph (ARG) of a 3D object. The proposed scheme recursively performs the constrained morphological decomposition (CMD) based on the mathematical morphology and weighted convexity. Then, a merging criterion based on the weighted convexity difference (WCD), which determines whether connected parts should be merged or not, is adopted for compact graph representation. The block diagram of the proposed scheme, in terms of three stages, is presented in Figure AMD2-1. The recursive decomposition stage (RDS) will be launched after the initial decomposition stage (IDS) and performed until QUEUE I is empty. Then, the iterative merging stage (IMS) is applied to parts in QUEUE II for the compact graph representation. Figure AMD2-2 shows the procedure of the proposed scheme for a ‘cow’ step by step. Figure AMD2-2 (a) and (b) show the ‘cow’ represented by rendered meshes and voxels, respectively. Then, Figure AMD2-2 (c), (d), and (e) show results of IDS, RDS, and IMS, respectively. Finally, the simple ARG representation is presented in Figure AMD2-2 (f), where the ellipsoidal node and edge represent the corresponding part and connectivity between parts, respectively.

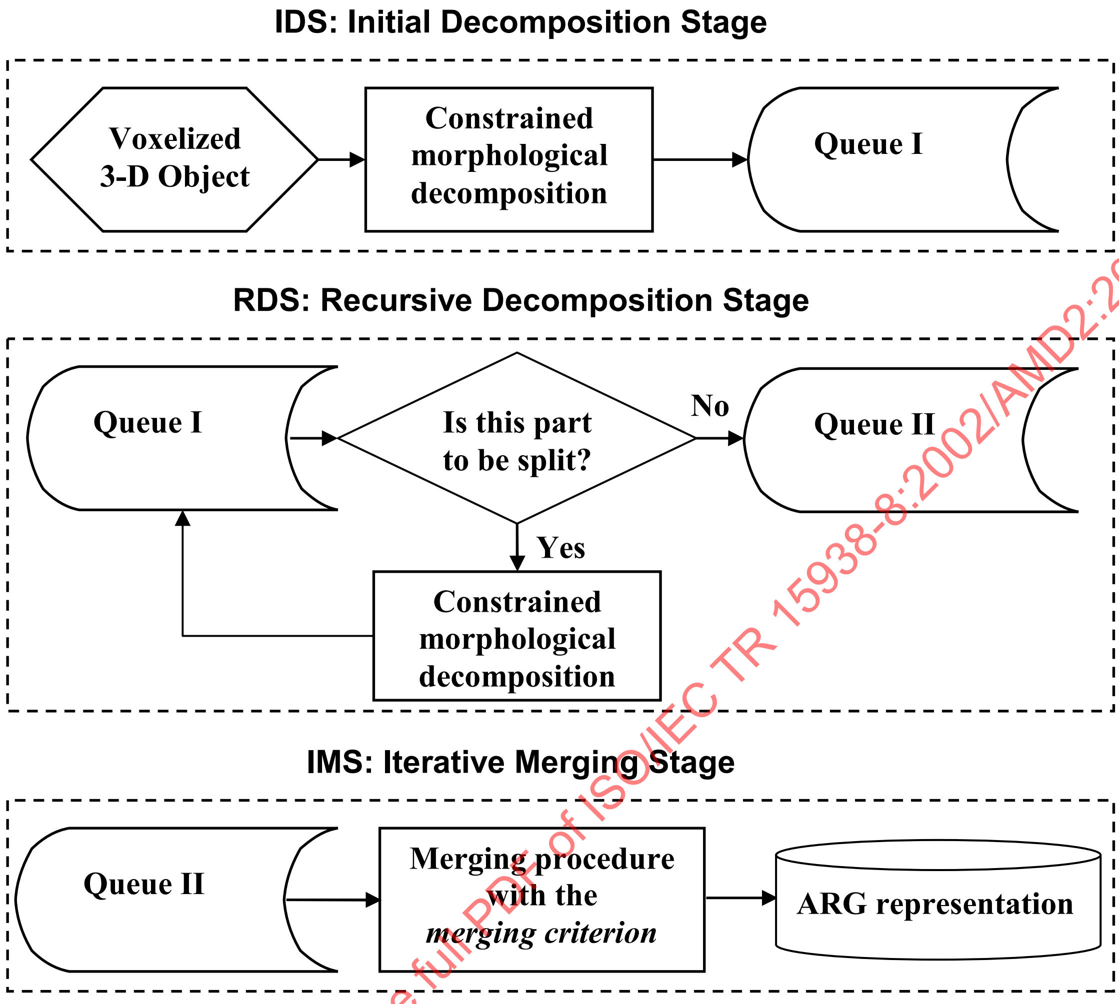
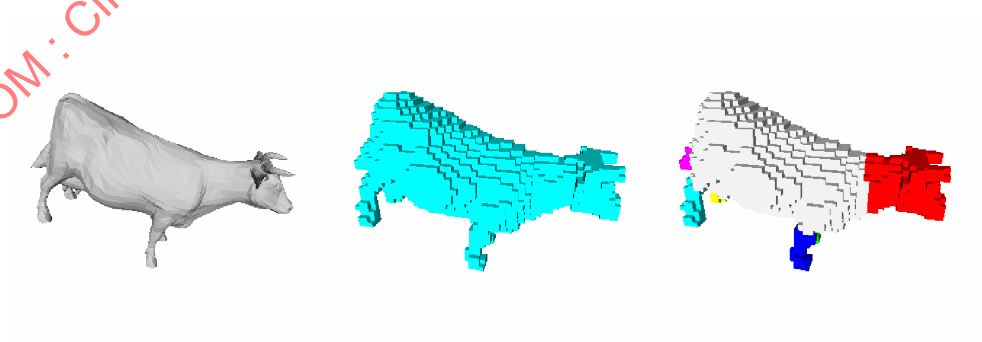
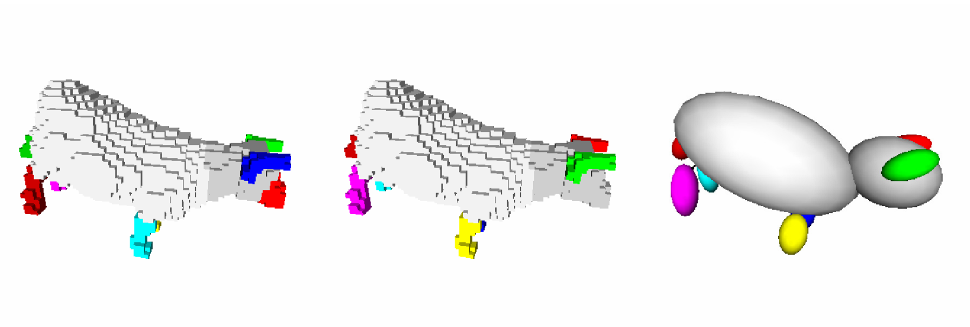


Figure AMD2-1 — The block diagram of the decomposition scheme



(a) (b) (c)



(d) (e) (f)

Figure AMD2-2 — The procedure of generating a part-based representation

8.6.2 Feature extraction

As described in the previous subclause, the Perceptual 3D Shape descriptor has the form of an ARG, composed of nodes and edges. A node represents a meaningful part of the model with unary attributes, while an edge implies binary relations between nodes. In order to obtain all attributes, principal component analysis (PCA) is performed on every part of the 3D model to find three principle axes, where the 1st principal axis corresponds to the principal direction with biggest variance, and the 3rd axis corresponds to the direction with smallest variance. Afterwards,, 4 unary attributes and 3 binary relations are extracted to form a Perceptual 3D Shape descriptor. In detail, a node is parameterized by volume v, convexity c, and two eccentricity values e_1 and e_2. More specifically, the convexity is defined as the ratio of the volume in a node to that in its convex hull, and the eccentricity is composed of two coefficients, $e_1 = \sqrt{1-c^2/a^2}$ and $e_2 = \sqrt{1-c^2/b^2}$, where a, b, and c (a ≥ b ≥ c) are the maximum ranges along 1st, 2nd, and 3rd principal axes, respectively. Then edge attributes, i.e. binary relations between two nodes, are extracted from the geometric relation between two nodes, in which the distance between centers of connected nodes and two angles are adopted. The first angle is the angle between the 1st principal axes of the connected nodes and the other is between their 2nd principal axes. All the unary attributes and binary relations are normalized into the interval [0, 1]. However, to adopt 'Query by sketch' in the retrieval system, the Perceptual 3D Shape descriptor is required to be represented by the set of ellipsoids. In this context, each ellipsoid contains three properties, such as Volume, Max (i.e. maximum range along each principle axes) and Convexity, which can easily be converted into the 4 unary attributes. Next, the Perceptual 3D Shape descriptor contains three properties, such as Center, PCA_Axis_1 and PCA_Axis_2 (i.e. 1st and 2nd principle axis) from which the 3 binary relations can be computed. Therefore, an actual Perceptual 3D Shape descriptor is created, as shown in Binary Representation Syntax. Note that Volume, Center, Max and Convexity are in the interval [0, 1], while the components in PCA_Axis_1 and PCA_Axis_2 are in the interval [-1, 1].

8.6.3 Similarity matching

The one-to-one comparison of two Perceptual 3D Shape descriptors consists of four steps: (1) Forming an ARG from every descriptor (Suppose that they are named as "query graph" and "model graph", respectively), (2) For each node in both graphs, defining Volume in Binary Representation Syntax as weight, (3) Calculating a distance matrix, where every element is the difference (distance) between any node-pair formed by any query graph node (named N_q) and any model graph node (named N_m), (4) Comparing the query and model graphs by employing the conventional Earth Mover's Distance (EMD) algorithm [AMD2-2], taking the node weights (from step-2) and the distance matrix (from step-3) as the input. In step-3 of this procedure, the calculation of the distance between N_q and N_m is fulfilled also by employing the EMD algorithm. This employment is named "Inner EMD", and the employment in step-4 is named "Outer EMD", thus the P3DS matching algorithm is named nested-EMD (nEMD).

Only step-3 needs more explanation. During this step, the distance between N_q and N_m is calculated as follows (from step-A to step-H): (A), their unary attributes are compared to give a "***unary-distance***". (B), a point set (named "Query Point Set") is constructed by N_q and all its connected nodes in the query graph. Every point is assigned a weight equal to the volume of its corresponding node. An imaginary point is also created and inserted to this point set, whose weight makes the sum of all set-points equal to one. (C) Another point set (named "Model Point Set") is constructed by N_m, all its connected nodes in the model graph, and a newly-introduced imaginary point, in the same way as step-B. (D) A vector space is constructed. The axes of its coordinate system represent the three measurements (one distance and two angles) of binary relations between connected nodes. $\boldsymbol{N_q}$ and $\boldsymbol{N_m}$ are located at the origin of this vector space, while other points (except imaginary points) are located so that their coordinate values are equal to their binary relation values with $\boldsymbol{N_q}$ (or $\boldsymbol{N_m}$). Figure AMD2-3 shows the connected nodes and the point locations in the vector space respectively for the query and model point sets. (E) Two graphs (named "***Nq-Graph***" and "***Nm-Graph***", respectively) are constructed with the Query and Model Point Set, respectively. (F) A binary-distance matrix is constructed by calculating the distances between all node-pairs between Nq-Graph and Nm-Graph. For calculating every binary-distance matrix element, if neither node is an imaginary point, the Euclidean distance in the vector space is used (marked as dots in Figure AMD2-4); if one node is an imaginary point, a constant value ***d*** is used (marked as "d" in Figure AMD2-4); otherwise the distance is zero (marked as "0" in Figure AMD2-4). (G) The conventional EMD algorithm is employed (Inner EMD) for comparing Nq-Graph and Nm-Graph, taking the graph nodes from step-E and the binary-distance matrix from step-F as the input, to calculate a distance value (named "***second-distance***"). (H) The unary-distance from step-A and the second-distance from step-G are summed to give the final result.

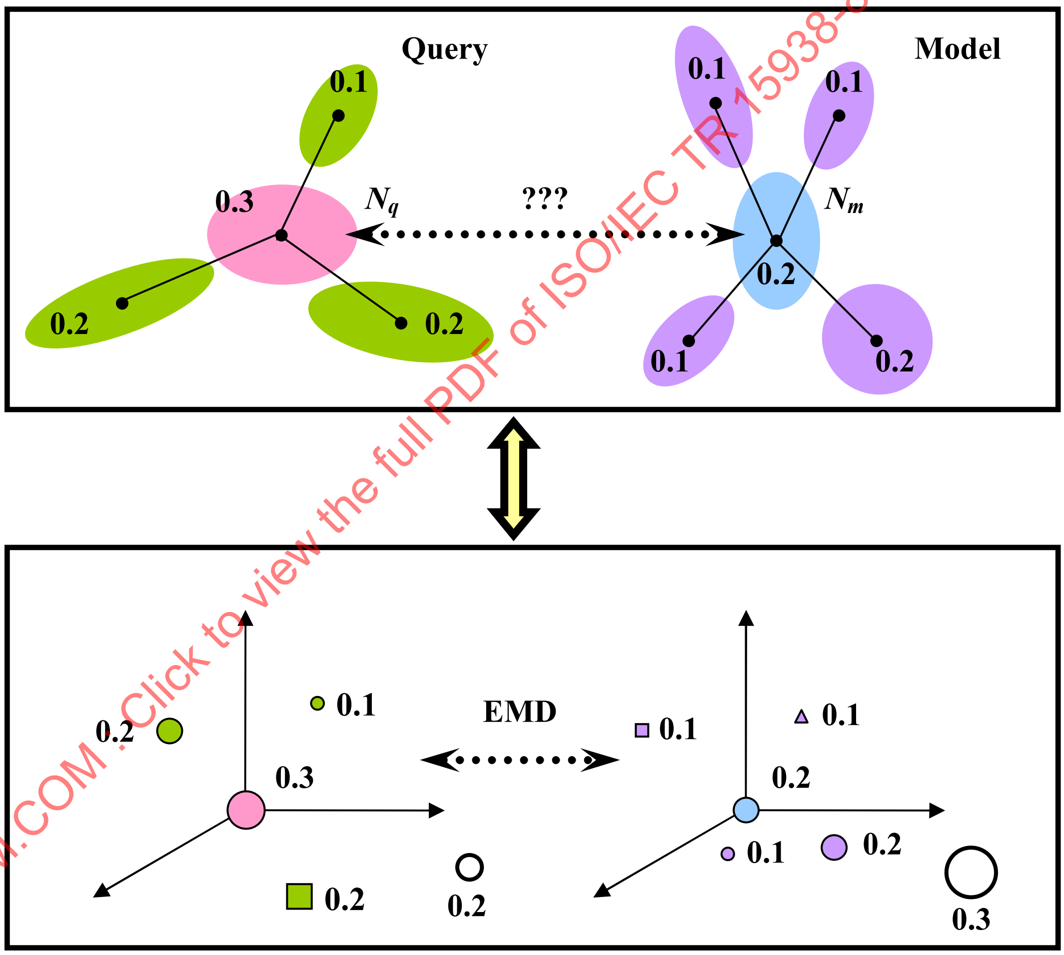


Figure AMD2-3 — Vector space representation for computing the Inner EMD

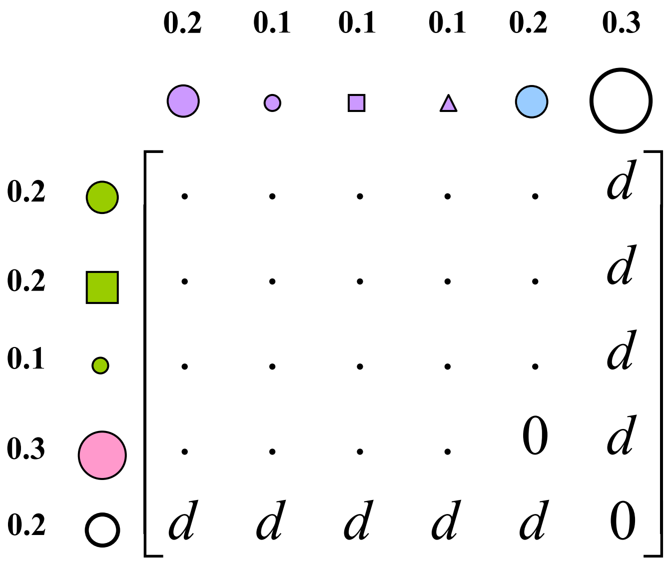


Figure AMD2-4 — Binary-distance matrix from the example in Figure AMD2-3

In the Outer EMD, the dissimilarity between the query and model graphs is measured by calculating the amount of work required to move the weights from the query nodes to the model nodes based on the final distance matrix. In other words, a total amount of work for all of the nodes refers to the dissimilarity between the two graphs.

8.6.4 Condition of use

The Perceptual 3D Shape descriptor is designed to represent and identify 3D graphic models based on a part-based simplified representation using ellipsoidal skeletons. It is based on the assumption that the part-based representation and the actual shape are coherent with human visual perception. If the encoder does not produce the part-based representation properly, the retrieval performance would not be good.

The retrieval efficiency is highly dependent on the BitsPerAttribute value. The recommended value of BitsPerAttribute is 6.

Depending on the encoding method, which creates a part-based representation from a query 3D model, the assumption of the 3D mesh model is different. For example, if the encoding method is based on volume-based part decomposition, the mesh model is assumed to have its own volume, i.e. the model is composed of one or more closed mesh surface. On the other hand, in case of mesh-based part decomposition, the mesh model is assumed to be manifold, i.e. an edge is shared by two triangles, unless it belongs to the boundary. For faster processing and better results, it is recommended to use a manifold mesh model with no holes.

8.6.5 Use scenario

A promising application scenario is 'Retrieval-based 3D graphic contents authoring' for the easy creation of 3D graphic contents. Currently most 3D graphic contents are created by intensive manual work of laborious mesh editing, which is very time consuming even for skilled designers. Therefore, it is known as the biggest obstacle in expanding the 3D graphics market. In the use scenario, this situation can be overcome by realizing 'Retrieval-based authoring of 3D-graphic contents', in which unskilled operators can create 3D-graphic contents very easily. In Figure AMD2-5, the general block diagram of the use scenario is shown. First, the user designs 3D objects by simple ellipsoidal links based on 'Query by sketch' (Figure AMD2-6 (a)), or selects 3D objects that are similar to what he wants ('Query by example'), or modifies the existing models by 'Query by modified example'. Second, the similar 3D objects are browsed from the model database (Figure AMD2-6 (b)), and then the user selects one of the retrieved models and replace the initial ellipsoidal model with it. Figure AMD2-6 (c) shows the final scene after performing 'Retrieval-based authoring of 3D graphic contents'.

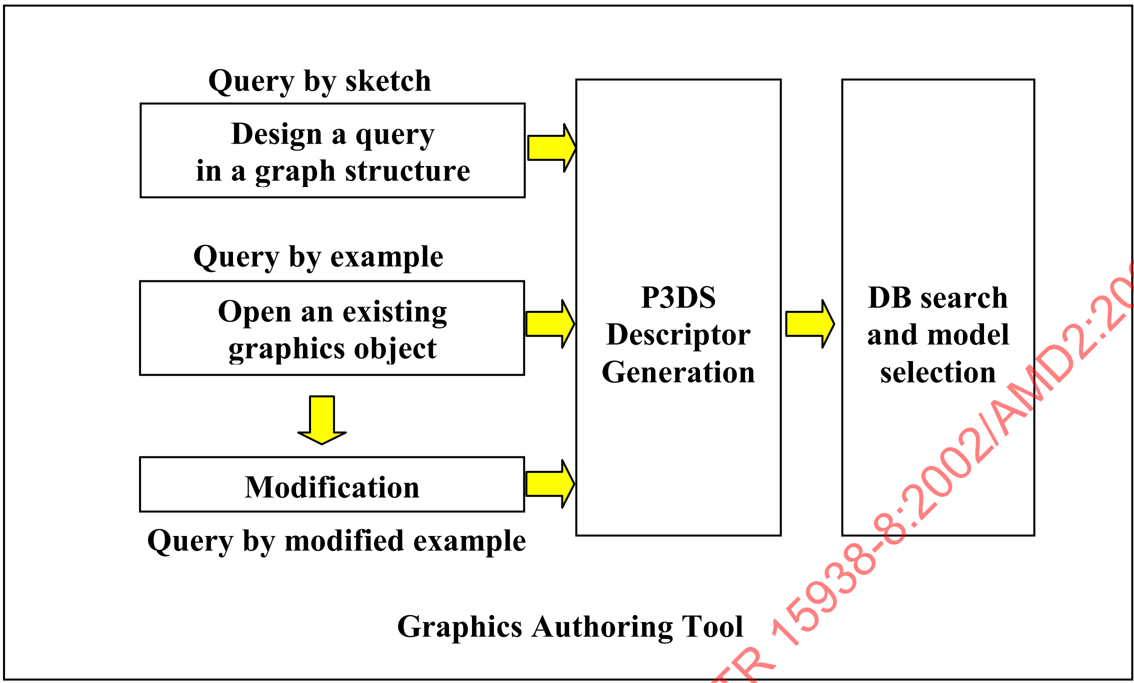
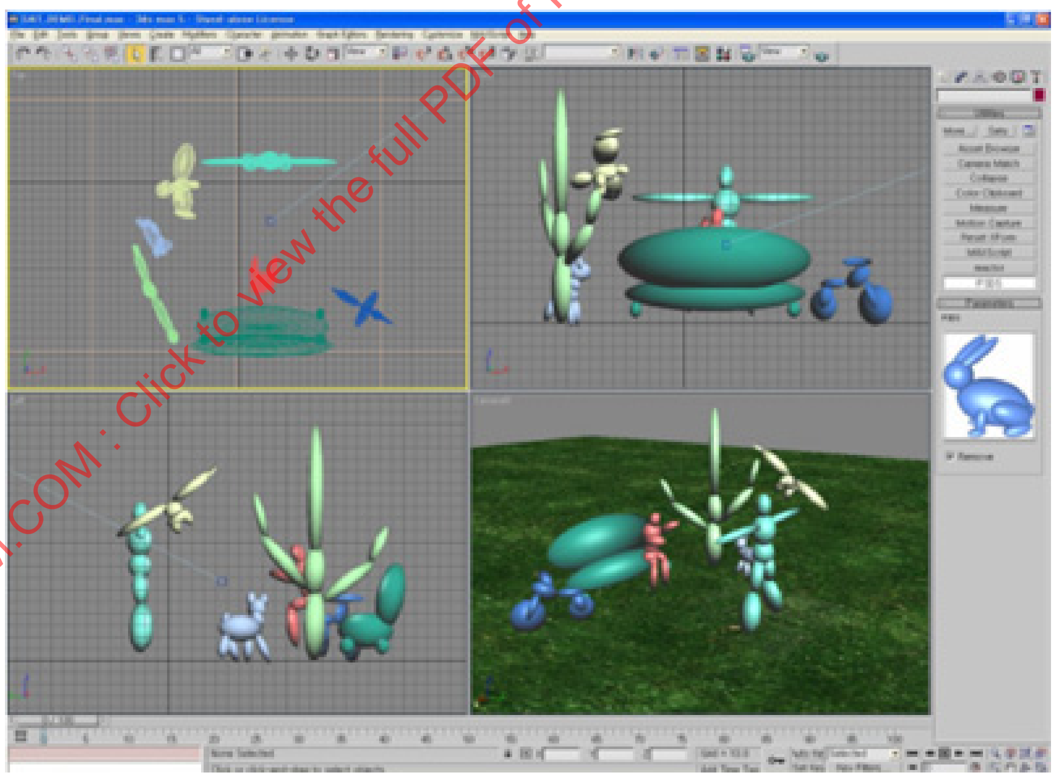
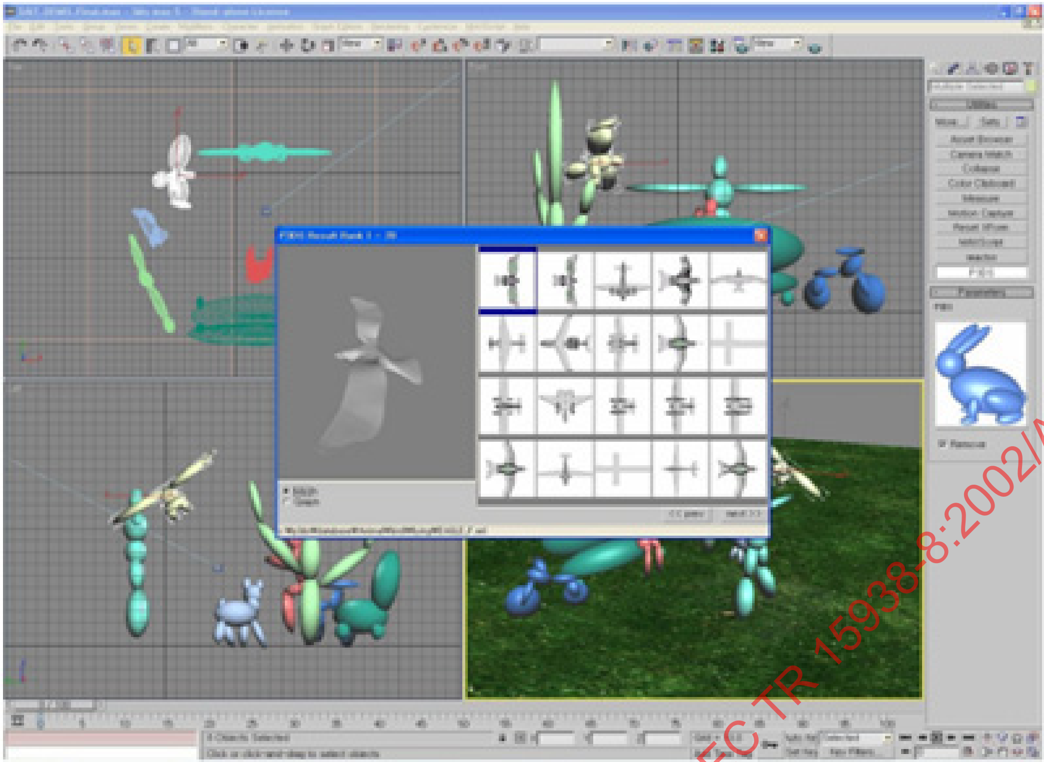


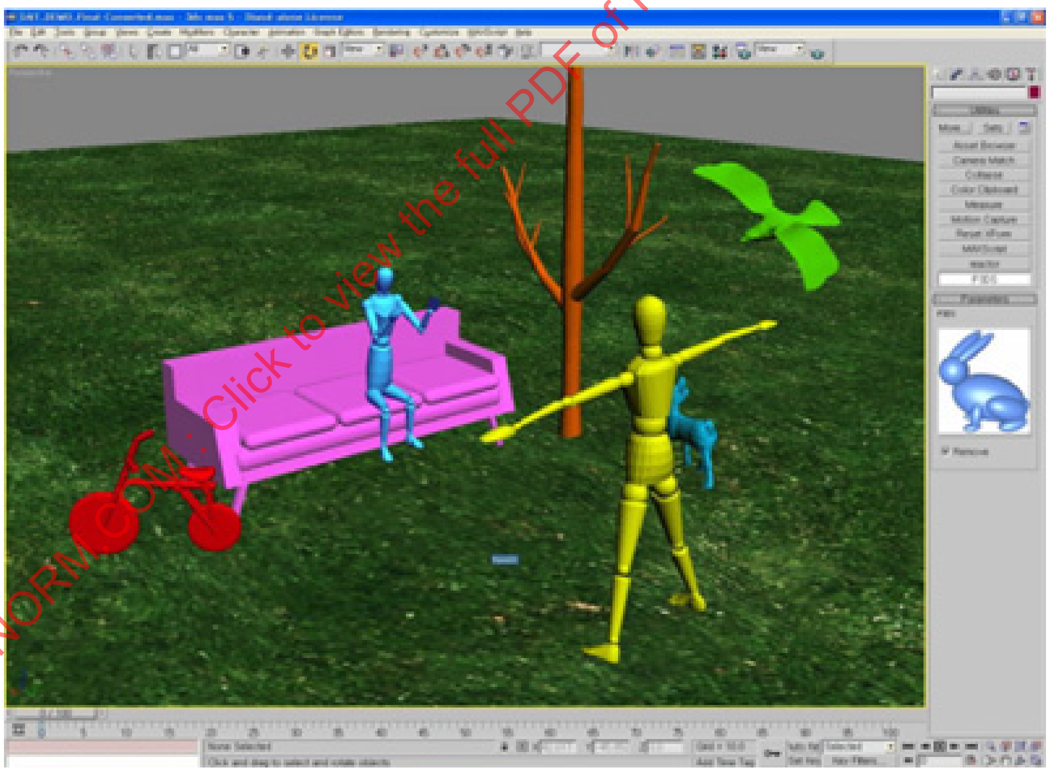
Figure AMD2-5 — The block diagram of the use scenario for the creation of 3D graphic contents



(a)



(b)



(c)

Figure AMD2-6 — The procedure of ‘Retrieval-based scene authoring tool’ for the creation of 3D graphic contents: (a) An initial blob world by modelling the scene using simple ellipsoids, (b) Performing database search for the bird and browsing the similar bird models, and (c) A final scene after performing ‘Retrieval-based authoring of 3D graphic contents’.