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Research Article

3D Model Search and Retrieval Using the Spherical Trace Transform

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This paper presents a novel methodology for content-based search and retrieval of 3D objects. After proper positioning of the 3D objects using translation and scaling, a set of functionals is applied to the 3D model producing a new domain of concentric spheres. In this new domain, a new set of functionals is applied, resulting in a descriptor vector which is completely rotation invariant and thus suitable for 3D model matching. Further, weights are assigned to each descriptor, so as to significantly improve the retrieval results. Experiments on two different databases of 3D objects are performed so as to evaluate the proposed method in comparison with those most commonly cited in the literature. The experimental results show that the proposed method is superior in terms of precision versus recall and can be used for 3D model search and retrieval in a highly efficient manner.

1. INTRODUCTION

With the general availability of 3D digitizers, scanners and the technology innovation in 3D graphics and computational equipment, large collections of 3D graphical models can be readily built up for different applications [1], that is, in CAD/CAM, games design, computer animations, manufacturing, and molecular biology. For example, a high number of new 3D structures of molecules have been stored in the worldwide repository Protein Data Bank (PDB) [2], where the number of the 3D molecular structure data increases rapidly, currently exceeding 24 000. For such large databases, the method whereby 3D models are sought merits careful consideration. The simple and efficient query-by-content approach has, up to now, been almost universally adopted in the literature. Any such method, however, must first deal with the proper positioning of the 3D models. The two prevalent in the literature methods for the solution to this problem seek either:

(i) *pose normalization*: models are first placed into a canonical coordinate frame (normalizing for translation, scaling, and rotation), then, the best measure of similarity is found comparing the extracted feature vectors; or

(ii) *descriptor invariance*: models are described in a transformation invariant manner, so that any transformation of a model will be described in the same way, and the best measure of similarity is obtained at any transformation.

1.1. Background and related work

1.1.1. Pose normalization

Most of the existing methods for 3D content-based search and retrieval of 3D models are applied following their placement into a canonical coordinate frame.

In [3] a fast querying-by-3D-model approach is presented, where the descriptors are chosen so as to mimic the basic criteria that humans use for the same purpose. More specifically, the specific descriptors that are extracted from the input model are the geometrical characteristics of the 3D objects included in the VRML such as the angles and edges that describe the outline of the model. Ohbuchi et al [4] employ shape histograms that are discretely parameterized along the principal axes of inertia of the model. The three shape histograms used are the moment of inertia about the axis, the average distance from the surface to the axis, and the variance of the distance from the surface to the axis. Osada et al. [5, 6] introduce and compare shape distributions, which measure properties based on distance, angle, area, and volume measurements between random surface points. They evaluate the similarity between the objects using a metric that measures distances between distributions.

In [7] an approach that measures the similarity among 3D models by visual similarity is proposed. The main idea is that if two 3D models are similar, they also look similar from all viewing angles. Thus, one hundred projections of an object are encoded both by Zernike moments and Fourier descriptors as characteristic features to be used for retrieval purposes.

In [8, 9] the authors present a method where the descriptor vector is obtained by forming a complex function on the sphere. Then, the fast Fourier transform (FFT) is applied on the sphere and Fourier coefficients for spherical harmonics are obtained. The absolute values of the coefficients form the descriptor vector.

In [10] a 3D search and retrieval method based on the generalized radon transform (GRT) is proposed. Two forms of the GRT are implemented: (a) the radial integration transform (RIT), which integrates the 3D model's information on lines passing through its center of mass and contains all the radial information of the model, and (b) the spherical integration transform (SIT), which integrates the 3D model's information on the surfaces of concentric spheres and contains all the spherical information of the model. Additionally, an approach for reducing the dimension of the descriptor vectors is proposed, providing a more compact representation (EnRIT), which makes the procedure for the comparison of two models very efficient.

The aforementioned methods are applied following model normalization. In general, models are normalized by using the center of mass for translation, the root of the average square radius for scaling, and the principal axes for rotation. While the methods for translation and scale normalization are robust for object matching [11], rotation normalization via PCA-alignment is not considered robust for many matching applications. This is due to the fact that PCA-alignment is performed by solving for the eigenvalues of the covariance matrix. This matrix captures only second-order model information, and the assumption when using PCA is that the alignment of higher frequency information is strongly correlated with the alignment of the second order components [12]. Further, PCA lacks any information about the direction (orientation) of each axis and finally, if the eigenvalues are equal, no unique set of principal axes can be extracted.

1.1.2. Descriptor invariance

Relatively few approaches for 3D-model retrieval have been reported in which pose estimation is unnecessary. Topology matching [13] is an interesting and intricate such technique, based on matching graph representations of 3D-objects. However, the method is suitable only for certain types of models.

The MPEG-7 shape spectrum descriptor [14] is defined as the histogram of the shape index, calculated over the entire surface of a 3D object. The shape index gives the angular coordinate of a polar representation of the principal curvature vector, and it is implicitly invariant with respect to rotation, translation and scaling.

In [15] a web-based 3D search system is developed that indexes a large repository of computer graphics models collected from the web supports queries based on 3D sketches, 2D sketches, 3D models, and/or text keywords. For the shape-based queries, a new matching algorithm was developed that uses spherical harmonics to compute discriminating similarity measures without requiring model alignment. In [12] a tool for transforming rotation-dependent spherical and voxel shape descriptors into rotation invariant ones is presented. The key idea of this approach is to describe a spherical function in terms of the amount of energy it contains at different frequencies. The results indicate that the application of the spherical harmonic representation improves the performance of most of the descriptors.

Novotni and Klein presented the 3D "Zernike" moments in [16]. These are computed as a projection of the function defining the object onto a set of orthonormal functions within the unit ball; their work was an extension of the 3D Zernike polynomials, which were introduced by Canterakis [17]. From these, Canterakis has derived affine invariant features of 3D objects represented by a volumetric function.

In [18], a 3D shape descriptor was proposed, which is invariant to rotations of 90 degrees around the coordinate axes. This restricted rotation invariance is attained by a very coarse shape representation computed by clustering point clouds. Since the normalization step is omitted, if an object is rotated around an axis by a different angle (e.g., by 45 degrees), the feature vector alters significantly.

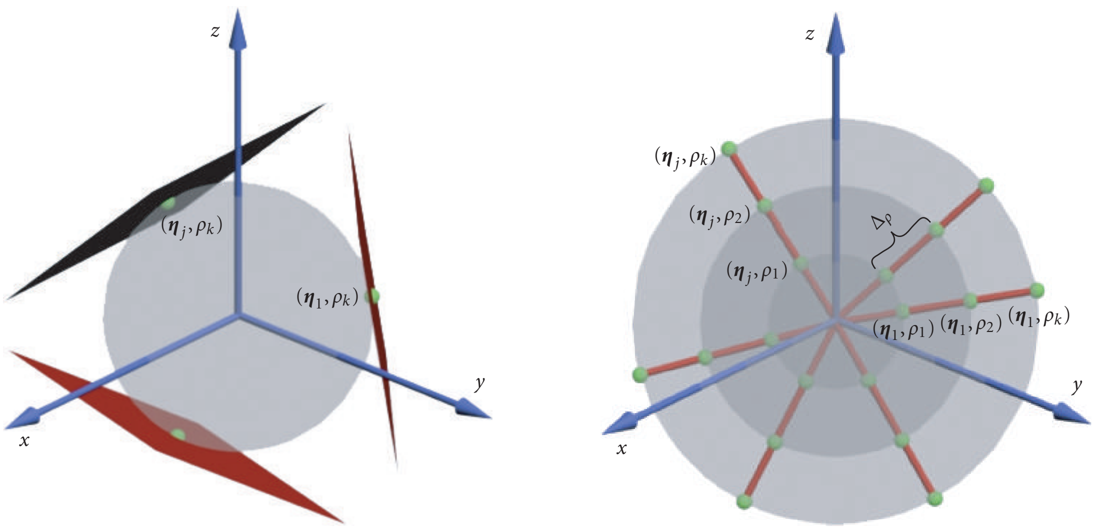
In this paper a novel framework of rotation invariant descriptors is constructed without the use of rotation normalization. An efficient 3D model search and retrieval method is then proposed. This is an extension of the 2D image search technique where the "trace transform" is computed by tracing an image (2D function) with straight lines along which certain functionals of the image are calculated [19].

The "spherical trace transform," proposed in this paper, consists of tracing the volume of a 3D model with

(i) radius segments,
(ii) 2D planes, tangential to concentric spheres.

Then using three sets of functionals with specific properties, completely rotation invariant descriptor vectors are produced.

The paper is organized as follows. In Section 2 the proposed framework with the mathematical background is given. Section 3 presents in detail the proposed descriptor extraction method. In Section 4 the matching algorithms used are described. Experimental results evaluating the proposed method and comparing it with other methods are presented in Section 5. Finally, conclusions are drawn in Section 6.



(a) (b)

Figure 1: The spherical trace transform.

2. THE SPHERICAL TRACE TRANSFORM

Let M be a 3D model and $f(\mathbf{x})$ the binary volumetric function of M, where $\mathbf{x} = [x, y, z]^T$, and

$$f(\mathbf{x}) = \begin{cases} 1 & \text{when } \mathbf{x} \text{ lies within the 3D model's volume,} \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Let us define plane $\Pi(\boldsymbol{\eta}, \rho) = \{\mathbf{x} \mid \mathbf{x}^T \cdot \boldsymbol{\eta} = \rho\}$ to be tangential to the sphere S_ρ with radius ρ and center at the origin, at the point $(\boldsymbol{\eta}, \rho)$, where $\boldsymbol{\eta} = [\cos\phi \sin\theta, \sin\phi \sin\theta, \cos\theta]$ is the unit vector in $\mathcal{R}^3$, and ρ a real positive number (Figure 1(a)). Additionally, let us define radius segment $\Lambda(\boldsymbol{\eta}, \rho) = \{\mathbf{x} \mid \mathbf{x}/|\mathbf{x}| = \boldsymbol{\eta},\ \rho \leq |\mathbf{x}| < \rho + \Delta_\rho\}$, where Δ_ρ is the length of the radius segment (Figure 1(b)).

The intersection of $\Pi(\boldsymbol{\eta}, \rho)$ with $f(\mathbf{x})$ produces a 2D function $\hat{f}(a, b)$, $(a, b \in \Pi(\boldsymbol{\eta}, \rho) \cap f(\mathbf{x}))$, which is then sampled and its discrete form $\hat{f}(i, j)$, $(i, j \in \mathcal{N})$ is produced. Similarly, the intersection of $\Lambda(\boldsymbol{\eta}, \rho)$ with $f(\mathbf{x})$ produces a 1D function $\check{f}(c)$ $(c \in \Lambda(\boldsymbol{\eta}, \rho) \cap f(\mathbf{x}))$ which is also sampled and its discrete form $\check{f}(i)$, $(i \in \mathcal{N})$ is produced. These two forms of data, $\hat{f}(i, j)$ and $\check{f}(i)$, will serve as input in the sequel.

The "spherical trace transform," proposed in this paper can be expressed using the general formulas

$$\begin{aligned} g_s(T; F; h) &= T(F(h(\cdot))), \\ g_a(T; A; F; h) &= T(A(F(h(\cdot)))), \end{aligned} \tag{2}$$

where

$$h(\cdot) = \begin{cases} \hat{f}(i, j), & \text{assuming representation using 2D planes} \\ \check{f}(i), & \text{assuming representation using radius segments} \end{cases} \tag{3}$$

and $F(\boldsymbol{\eta}, \rho)$ denotes an "initial functional," which can be applied to each $\hat{f}(i, j)$ or $\check{f}(i)$, that is, $F(\boldsymbol{\eta}, \rho) = F(\hat{f}(i, j))$ or $F(\boldsymbol{\eta}, \rho) = F(\check{f}(i))$. The set of $F(\boldsymbol{\eta}, \rho)$ is treated either as a collection of spherical functions $\{F^\rho(\boldsymbol{\eta})\}_\rho$ parameterized by ρ, or as a collection of radial functions $\{F^{\boldsymbol{\eta}}(\rho)\}_{\boldsymbol{\eta}}$ parameterized by $\boldsymbol{\eta}$.

In the first case, a set of "spherical functionals" $T(\rho)$ is applied to each $F^\rho(\boldsymbol{\eta})$, producing a descriptor vector $g_s(T) = T(F^\rho(\boldsymbol{\eta}))$.

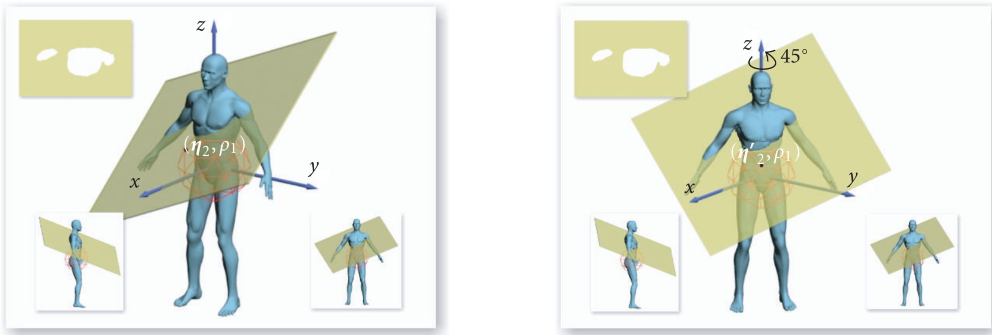
In the second case, a set of "actinic functionals" $A(\boldsymbol{\eta})$ is applied to each $F^{\boldsymbol{\eta}}(\rho)$, producing the $A(\boldsymbol{\eta}) = A(F^{\boldsymbol{\eta}}(\rho))$. Then, the T functionals are applied to $A(\boldsymbol{\eta})$, generating another descriptor vector $g_a(T) = T(A(\boldsymbol{\eta}))$.

Let us now examine the conditions that must be satisfied by the functionals in order to produce rotation invariant descriptor vectors. Under a 3D object rotation governed by a 3D rotation matrix $\mathbf{R}$, the points $\boldsymbol{\eta}$ will be rotated:

$$\boldsymbol{\eta}' = \mathbf{R} \cdot \boldsymbol{\eta}, \tag{4}$$

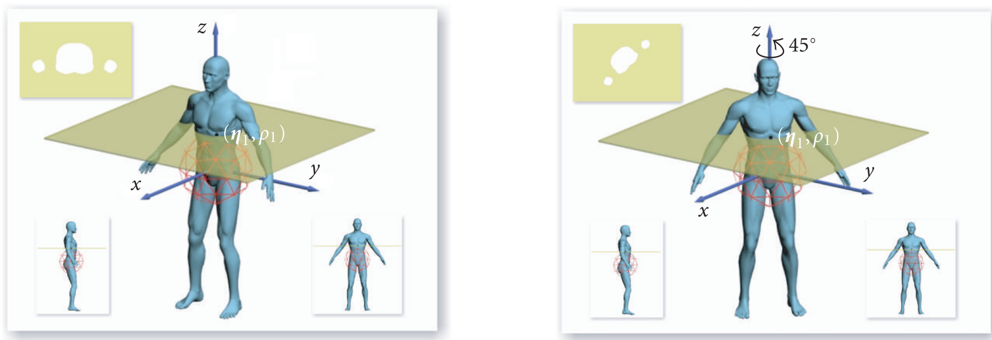
therefore

$$F(\boldsymbol{\eta}', \rho) = F(\mathbf{R} \cdot \boldsymbol{\eta}, \rho) \tag{5}$$



(a) (b)

Figure 2: Rotation of $f(\mathbf{x})$ rotates $F(\boldsymbol{\eta}, \rho)$, without rotating the corresponding $f(i, j)$ (upper left image). Thus, $F(\boldsymbol{\eta}_2, \rho_1) = F(\boldsymbol{\eta}'_2, \rho_1)$.



(a) (b)

Figure 3: Rotation of $f(\mathbf{x})$ rotates $\hat{f}(i, j)$ (upper left image) without causing a rotation of the point $(\boldsymbol{\eta}_1, \rho_1)$.

and thus, rotation invariant T functionals must be applied, so that $T(F(\boldsymbol{\eta}', \rho)) = T(F(\boldsymbol{\eta}, \rho))$ (Figure 2).

In the specific case where the points $\boldsymbol{\eta}$ lie on the axis of rotation the corresponding $\hat{f}(i, j)$ will be rotated (Figure 3), that is,

$$\hat{f}'(i, j) = \hat{f}(i', j') \tag{6}$$

and thus, 2D rotation invariant functionals must be applied, so that $F(\hat{f}'(i, j)) = F(\hat{f}(i', j'))$. Therefore, a general solution is given using 2D rotation invariant functionals F and rotation invariant spherical functionals T, producing completely rotation invariant descriptor vectors.

The functionals which satisfy the above-stated conditions, as initial, actinic, and spherical, will be briefly discussed in the following section.

The advantage of this approach is threefold: firstly, the rotation normalization which hampers the performance of the descriptors in most 3D search approaches, is avoided. Secondly, the possibility of constructing a large number of descriptor vectors is presented. Indeed, the recognition of 3D objects is facilitated when a large number of features are present and in fact, the more classes must be distinguished, the more features may be necessary. The proposed method permits the construction of a large number of invariant features by defining a sufficient number of F, A, and T functionals. Thirdly, the use of the T functionals leads to the definition of descriptor vectors with low dimensionality since each T functional produces a single number per concentric sphere. Thus, a compact representation of the descriptor vectors is achieved, which in turn simplifies the comparison between two models.

Another advantage of the proposed method is that it overcomes the problem analyzed in [12, Section 5.2] that face all the existing algorithms that use a rotation invariant transformation applied on concentric spheres. When independent rotations are applied on an object at specific radius, an object of totally different shape will be produced. Because of the integration over all shells of the same radius, all these methods will produce identical descriptors for these totally different objects. The proposed method will not be affected of such a transformation, since in the case of decomposing the object's volume in 2D planes, the planes will contain information of the object in different radius. Moreover, the actinic functionals will be applied on the results from the previous step, that all share the same angular position, thus information on the different spheres will be combined. These two facts will assure that objects, of totally different shape, produced from transformations of independent rotations on an object, will not produce identical descriptors.

In the following a brief description of the functionals that were selected will be given.

2.1. Initial functionals F

2.1.1. The "mutated" radial integration transform (RIT)

Let $\Lambda(\boldsymbol{\eta}, \rho) = \{\mathbf{x} \mid \mathbf{x}/|\mathbf{x}| = \boldsymbol{\eta},\ \rho \leq |\mathbf{x}| < \rho + \Delta_\rho\}$ be a radius segment (Figure 1(b)). Let also $\check{f}_t(i)$ be the discrete function, which is derived from $\check{f}_t(c)$. $\check{f}_t(c)$ is produced from the intersection of $f(\mathbf{x})$ with the $\Lambda(\boldsymbol{\eta}_t, \rho_t)$ which begins from the point $(\boldsymbol{\eta}_t, \rho_t)$ and ends at the point $(\boldsymbol{\eta}_t, \rho_t + \Delta_\rho)$. Then, the "mutated" radial integration transform $\text{RIT}(\boldsymbol{\eta}, \rho)$ [10] is defined as:

$$\text{RIT}\,(\boldsymbol{\eta}_t, \rho_t) = \sum_{i=0}^{N-1} \check{f}_t(i), \tag{7}$$

where $t = 1, \ldots, N_R$, N_R is the total number of radius segments, and N is the total number of sampled points on each line segment.

2.1.2. 1D Fourier transform

The 1D discrete Fourier transform of $\check{f}_t(i)$ is calculated, producing the vectors $\text{DF}_t(k)$, where $t = 1, \ldots, N_R$, N_R is the total number of radius segments, and $k = 0, \ldots, N-1$, N is the total number of sampled points on each radius segment. The vectors contain only the first K harmonic amplitudes. As a result, the 1D DFT generates K different initial functionals.

2.1.3. The 3D Radon transform

Let $\Pi(\boldsymbol{\eta}, \rho) = \{\mathbf{x} \mid \mathbf{x}^T \cdot \boldsymbol{\eta} = \rho\}$ be a plane (Figure 1(a)). Let also $\hat{f}_t(i, j)$ be the discrete function, which is derived from $\hat{f}_t(a, b)$. The function $\hat{f}_t(a, b)$ is produced from the intersection of $f(\mathbf{x})$ with $\Pi(\boldsymbol{\eta}_t, \rho_t)$, which is tangential to the sphere with radius ρ_t at the point $(\boldsymbol{\eta}_t, \rho_t)$. Then, the 3D radon transform $R(\boldsymbol{\eta}, \rho)$ is defined as

$$R(\boldsymbol{\eta}_t, \rho_t) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \hat{f}_t(i, j), \tag{8}$$

where $t = 1, \ldots, N_R$, N_R is the total number of planes ($\equiv$ total number of radius segments), and $N \times N$ are the sampled points on each plane.

2.1.4. The Polar-Fourier transform

The discrete Fourier transform (DFT) is computed for each $\hat{f}_t(i, j)$, producing the vectors $\text{FT}_t(k, m)$, where $k, m = 0, \ldots, N-1$ and $t = 1, \ldots, N_R$. Considering the first $\mathcal{K} \times M$ harmonic amplitudes for each $\hat{f}_t(i, j)$, the polar-DFT generates $\mathcal{K} \times M$ different initial functionals.

2.1.5. Hu moments

Moment invariants have become a classical tool for 2D object recognition. They were firstly introduced by Hu [20], who employed the results of the theory of algebraic invariants [21] and derived the seven well-known Hu moments, ϕ_i, $i = 1, \ldots, 7$, which are invariant to the rotation of 2D objects. They are calculated for each $\hat{f}_t(i, j)$ with spatial dimension $N \times N$, producing the vectors HU_i^t, where $i = 1, \ldots, 7$ and $t = 1, \ldots, N_R$.

2.1.6. Zernike moments

Zernike moments are defined over a set of complex polynomials which forms a complete orthogonal set over the unit disk and are rotation invariant. The Zernike moments Z_{km} [22], where $k \in N^+$, $m \leq k$, are calculated for each $\hat{f}_t(i, j)$ with spatial dimension $N \times N$, producing the vectors Z_t^{km}.

2.1.7. Krawtchouk moments

Krawtchouk moments are a set of moments formed by using Krawtchouk polynomials as the basis function set. Following the analysis in [23] and some specifications mentioned in [24], they were computed for each $\hat{f}_t(i, j)$ producing the vectors K_t^{km}.

2.1.8. The 2D Polar wavelet transform

The 2D wavelet transform includes the convolution of the two-dimensional function $\hat{f}_t(i, j)$ with a pair of QMF filters, followed by downsampling by a factor of two. In order to produce rotation invariant features, $\hat{f}_t(i, j)$ should be transformed to the polar coordinate system, resulting in the Polar wavelet transform [25]. In the first level of decomposition, four different subbands are produced. The rotation invariant functionals WT_t^{km} are derived by computing an energy signature for each subband $(k, m = 0, 1)$. In this paper, the Daubechies D_6 wavelet [26] was chosen as an appropriate pair of filters.

Each of the aforementioned F functionals produces a value (in case of RIT and Radon), or more values (in all other cases), per plane or per radius segment. The entire set of values for each initial functional F generates a function $F(\boldsymbol{\eta},\rho)$ whose domain consists of concentric spheres.

2.2. Actinic functionals A

The $F(\boldsymbol{\eta},\rho)$ produced as above is now treated as a collection of radial functions $F^{\boldsymbol{\eta}}(\rho)$ by restricting at different $\boldsymbol{\eta}$. Then, the following set of "actinic functionals" $A_i(\boldsymbol{\eta})$, $i = 1,\dots,4$, is applied to each $F^{\boldsymbol{\eta}}(\rho_t)$:

(1) $A_1(\boldsymbol{\eta}) = \mathrm{DF}(F^{\boldsymbol{\eta}}(\rho_t)) = \mathrm{DF}_k^{\boldsymbol{\eta}}(\rho_t)$,
(2) $A_2(\boldsymbol{\eta}) = \max\{F^{\boldsymbol{\eta}}(\rho_t)\}$,
(3) $A_3(\boldsymbol{\eta}) = \max\{F^{\boldsymbol{\eta}}(\rho_t)\} - \min\{F^{\boldsymbol{\eta}}(\rho_t)\}$,
(4) $A_4(\boldsymbol{\eta}) = \sum_{t=1}^{N_r} |F'^{\boldsymbol{\eta}}(\rho_t)|$,

where F' is the derivative of F, $t = 1,\dots,N_r$ are sample points on each $\boldsymbol{\eta}$, and N_r is their total number.

2.3. Spherical functionals T

The set of functionals T, which is applied to each $F^{\rho}(\boldsymbol{\eta})$ and $A_i(\boldsymbol{\eta})$, in order to produce the descriptor vector, includes

(1) $T_1(\omega) = \max\{\omega(\boldsymbol{\eta}_j)\}$, $j = 1,\dots,N_s$,
(2) $T_2(\omega) = \sum_{j=1}^{N_s} |\omega'(\boldsymbol{\eta}_j)|$,
(3) $T_3(\omega) = \sum_{j=1}^{N_s} \omega(\boldsymbol{\eta}_j)$,
(4) $T_4(\omega) = \max\{\omega(\boldsymbol{\eta}_j)\} - \min\{\omega(\boldsymbol{\eta}_j)\}$, $j = 1,\dots,N_s$,
(5) the amplitudes of the first L harmonics of the spherical Fourier transform (SFT), applied on $\omega(\boldsymbol{\eta}_j)$, which are also called as the "rotationally invariant shape descriptors" A_l [27]. In the proposed method, for each l, $l = 1,\dots,L$, the corresponding A_l is a spherical functional T,

where $\omega(\boldsymbol{\eta}_j) = F^{\rho}(\boldsymbol{\eta}_j)$ or $\omega(\boldsymbol{\eta}_j) = A_i(\boldsymbol{\eta}_j)$, ω' its derivative, and $N_s = N_R/N_c$, where N_c is the total number of concentric spheres.

In our case,

$$\omega(\boldsymbol{\eta}) = \begin{cases} \mathrm{RIT}^{\rho}(\boldsymbol{\eta}), \\ \mathrm{DF}_k^{\rho}(\boldsymbol{\eta}), \\ R^{\rho}(\boldsymbol{\eta}), \\ \mathrm{FT}_{km}^{\rho}(\boldsymbol{\eta}), \\ \mathrm{HU}_k^{\rho}(\boldsymbol{\eta}), \\ Z_{km}^{\rho}(\boldsymbol{\eta}), \\ K_{km}^{\rho}(\boldsymbol{\eta}), \\ \mathrm{WT}_{km}^{\rho}(\boldsymbol{\eta}), \\ A(\boldsymbol{\eta}). \end{cases} \quad (9)$$

Concluding this section, it should be noted that the total number of spherical functionals T used is $L+4$ for each concentric sphere.

3. DESCRIPTOR EXTRACTION PROCEDURE

3.1. Preprocessing

A 3D model M is generally described by a 3D mesh. Let $R\times R\times R$ be the size of the smallest cube bounding the mesh. The bounding cube is partitioned in $(2\cdot N)^3$ equal cube shaped voxels u_i with centers $\mathbf{v}_i = [x_i, y_i, z_i]$, where $i = 1,\dots,(2\cdot N)^3$. The size of each voxel is $(R/(2\cdot N))^3$. Let U be the set of all voxels inside the bounding cube and $U_1 \subseteq U$, be the set of all voxels belonging to the bounding cube and lying inside M. Then, the discrete binary volume function $\widetilde{f}(\mathbf{v}_i)$ of M, is defined as

$$\widetilde{f}(\mathbf{v}_i) = \begin{cases} 1 & \text{when } u_i \in U_1, \\ 0 & \text{otherwise.} \end{cases} \quad (10)$$

In order to achieve translation invariance, the center of mass of the model is first calculated. Then, the model is translated so that the center of mass coincides with the center of the bounding cube. Translation invariance follows.

To achieve scaling invariance, the maximum distance $d_{\max}$ between the center of mass and the most distant voxel, where $\widetilde{f}(\mathbf{v}_i) = 1$, is calculated. Then, the translated $\widetilde{f}(\mathbf{v}_i)$ is scaled so that $d_{\max} = 1$. At this point, scaling invariance is also accomplished.

A coarser mesh is then constructed by combining every eight neighboring voxels u_i, to form a bigger voxel ν_k with centers ν_k, $k = 1\dots,N^3$. The discrete integer volume function $\widetilde{f}(\nu_k)$ of M is defined as

$$\widetilde{f}(\nu_k) = \sum_{n=1}^{8} \widetilde{f}(\mathbf{v}_n) : u_n \in \nu_k. \quad (11)$$

Thus, the domain of $\widetilde{f}(\nu_k)$ is $[0,\dots,8]$. The procedure described in Section 2 is then applied to the function $\widetilde{f}(\nu_k)$ instead of the function $f(\mathbf{x})$. Specifically, $\widetilde{f}(\nu_k)$ is assumed to intersect with planes. Each plane is tangential to the sphere with radius ρ at the point B. Further, $\widetilde{f}(\nu_k)$ is assumed to intersect with radius segments.

In order to avoid possible sampling errors caused using the lines of latitude and longitude (since they are too much concentrated towards the poles), each concentric sphere is simulated by an icosahedron where each of the 20 main triangles is iteratively subdivided into q equal parts to form sub-triangles. The vertices of the subtriangles are the sampled points B_t. Their total number N_s, for each concentric sphere (icosahedron) C_s, with radius ρ_s, $s = 1,\dots,N_c$, where N_c is the total number of concentric spheres, is easily seen to be

$$N_s = 10\cdot q^2 + 2. \quad (12)$$

3.2. Descriptor extraction

Each function $\widehat{f}_t(a,b)$, $t = 1,\dots,N_s$, is quantized into $N\times N$ samples and its discrete form $\widehat{f}_t(i,j)$ is produced. The domain of $\hat{f}_t(i,j)$ is $[0,\ldots,8]$. Similarly, each function $\hat{f}_t(c)$ is quantized into N samples and its discrete form $\check{f}_t(i)$ is produced. The domain of $\check{f}_t(i)$ is $[0,\ldots,8]$.

Then, the procedure described in Section 2 is followed for each functional F, producing the descriptor vectors $g_s(T) = T(F^{\rho_t}(\boldsymbol{\eta}_t)) = \mathbf{D1}_F(l_1)$, and $g_a(T) = T(A(\boldsymbol{\eta}_t)) = \mathbf{D2}_F(l_2)$, where $l_1 = 1,\ldots,(L+4)\cdot N_c$, $l_2 = 1,\ldots,(L+4)\cdot 4$ and L is the total number of spherical harmonics. The integrated descriptor vector is $\mathbf{D}_F(l) = [\mathbf{D1}_F(l_1), \mathbf{D2}_F(l_2)]^T$, where $l = 1,\ldots,\{(L+4)\cdot N_c + (L+4)\cdot 4\}$.

The same procedure is followed for all F functionals, producing the descriptor vectors $\mathbf{D}_{\text{RIT}}(l)$, $\mathbf{D}_{\text{DF}_k}(l)$, $\mathbf{D}_R(l)$, $\mathbf{D}_{\text{HU}_k}(l)$, $\mathbf{D}_{\text{FT}_{km}}(l)$, $\mathbf{D}_{Z_{km}}(l)$, $\mathbf{D}_{K_{km}}(l)$, and $\mathbf{D}_{\text{WT}_{km}}(l)$.

Our experiments presented in the sequel were performed using the values $N_R = 2562$, $N_c = 20$, $L = 26$, $K = 8$, and $N = 64$.

4. MATCHING ALGORITHM

Let A, B be two 3D models. Let also $\mathbf{D}^A(k) = [\mathbf{D}^{A1}(k_1), \mathbf{D}^{A2}(k_2)]^T$, $\mathbf{D}^B(k) = [\mathbf{D}^{B1}(k_1), \mathbf{D}^{B2}(k_2)]^T$ be two descriptor vectors of the same kind $\mathbf{D}(\mathbf{k})$. The model descriptors are compared in pairs using their $L1$-distance:

$$D1_{\text{similarity}} = \sqrt{\sum_{k1=1}^{(L+4)\cdot N_c} \left|\mathbf{D}^{A1}(k1) - \mathbf{D}^{B1}(k1)\right|},$$
$$D2_{\text{similarity}} = \sqrt{\sum_{k2=1}^{(L+4)\cdot 4} \left|\mathbf{D}^{A2}(k2) - \mathbf{D}^{B2}(k2)\right|}. \tag{13}$$

The overall similarity measure is determined by

$$D_{\text{similarity}} = a_1 \cdot D1_{\text{similarity}} + a_2 \cdot D2_{\text{similarity}}, \tag{14}$$

where a_1, a_2 are descriptor vector percentage factors, which are calculated as follows. Let us assume that A belongs to a class C, which contains N_C models. Let also N_{total} be the total number of models contained in the database. Then the factor a_1 is calculated as

$$a_1 = \frac{\sum_{i=1}^{N_C} d_i}{\sum_{j=1}^{N_{\text{total}}-N_C} d_j}, \tag{15}$$

where d_i is the $L1$-distance of the descriptor vector $\mathbf{D}^{A1}$ of the model A from the descriptor vector $D^{A1'}$ of the model A' which also belongs to C, and d_j is the $L1$-distance of the descriptor vector $\mathbf{D}^{A1}$ of the model A from the descriptor vector $\mathbf{D}^{A1''}$ of the model A'' which does not belong to C. The combination, small d_i and big d_j, implies that the descriptor vector $\mathbf{D}^{A1}$ is good for the class C, in terms of successful retrieved results. The percentage factor a_2 is calculated similarly taking into account the descriptor vector $\mathbf{D}^{A2}$. Then a_1 and a_2 are normalized so that $1/a_1 + 1/a_2 = 100$.

Following the above approach, a large number of descriptor vectors can be efficiently used, taking advantage of the discriminative power of each descriptor vector per different class.

Experiments have shown that a single descriptor vector does not outperform all the others, in terms of precision recall, in all different classes, thus using the percentage factors we take advantage of the real discriminative power of each descriptor vector per each different class. Such an approach has not been reported so far in this research field.

4.1. Assigning weights to each class

In this section, a procedure for the calculation of weights characterizing the discriminative power of each descriptor vector per different class is described.

Let $\mathbf{D}^i(j) = [D^i(1), \ldots, D^i(S)]$ be a descriptor vector, where $i = 1,\ldots,N_{\text{total}}$. N_{total} is the total number of 3D models and S is the total number of descriptors per descriptor vector. Let also C be a class with descriptor vectors:

$$M_C = \begin{bmatrix} D^1(1) & \ldots & D^1(k) & \ldots & D^1(S) \\ & \ldots & & & \\ D^i(1) & \ldots & D^i(k) & \ldots & D^i(S) \\ & & & \ldots & \\ D^{N_C}(1) & \ldots & D^{N_C}(k) & \ldots & D^{N_C}(S) \end{bmatrix}, \tag{16}$$

where N_C is the number of 3D models which belongs to class C.

Then, the *feature vectors* $\mathbf{f}_{C1},\ldots,\mathbf{f}_{Ck},\ldots,\mathbf{f}_{CS}$ are formed, where $C = 1,\ldots,N_{\text{class}}$, $\mathbf{f}_{Ck} = [D^1(k)\cdots D^i(k)\cdots D^{N_C}(k)]^T$, and N_{class} is the total number of classes.

For each $\mathbf{f}_{Ck}$, the mean

$$\mu_{\mathbf{f}_{Ck}} = \frac{1}{N_C}\sum_{i=1}^{N_C} D^i(k) \tag{17}$$

and the variance

$$\sigma^2_{\mathbf{f}_{Ck}} = \frac{1}{N_C}\sum_{i=1}^{N_C}\left(D^i(k)\right)^2 - \left(\mu_{\mathbf{f}_{Ck}}\right)^2 \tag{18}$$

are calculated. The magnitude of each weight W_{Ck} depends on two factors.

(i) *The compactness factor* $W^{(1)}$: the $W^{(1)}$ factor provides a measure of the compactness of the $\mathbf{f}_{Ck}$ feature vector for the class C. It is calculated by

$$W^{(1)}_{Ck} = \frac{\sigma_{\mathbf{f}_{Ck}}}{\mu_{\mathbf{f}_{Ck}}}. \tag{19}$$

The lower the value of $W^{(1)}_{Ck}$ the higher the weight of the kth feature vector of Cth class.

(ii) *The dissimilarity factor* $W^{(2)}$: the $W^{(2)}$ factor provides a measure of dissimilarity between the feature vector $\mathbf{f}_{Ck}$ of the class C and the corresponding feature vector $\mathbf{f}_{C1k}$ of the class $C1$. The higher the $W^{(2)}_{Ck}$ factor the more dissimilar is the kth feature vector of C class ($\mathbf{f}_{Ck}$) when compared to the kth feature vectors of the other classes. Specifically, for the kth feature vector of Cth class, the number M_{Ck} of the descriptors $D^n(k)$, where $n \in ([1,\dots,N_{\text{class}}] - C)$, which do not belong to $[\mu_{\mathbf{f}_{Ck}} - \sigma_{Ck}, \mu_{\mathbf{f}_{Ck}} + \sigma_{Ck}]$ is calculated, and the $W^{(2)}$ factor is evaluated using

$$W^{(2)}_{Ck} = \frac{M_{Ck}}{N_{\text{total}} - N_C}, \tag{20}$$

where N_{total} is the total number of 3D models and N_C is the number of models of the Cth class. The final weights are calculated by

$$W_{Ck} = C_1\left(1 - W^{(1)}_{Ck}\right) + C_2 W^{(2)}_{Ck}, \tag{21}$$

where $C_1, C_2 \in [0,1]$ are coefficients and

$$C_1 + C_2 = 1. \tag{22}$$

It is obvious that

$$0 \le W_{Ck} \le 1. \tag{23}$$

It was experimentally found that best results were obtained for $C_1 \in [0.2, 0.4]$ and $C_2 \in [0.6, 0.8]$.

A 2D array of weights is then created, for all models in database,

$$\mathbf{W} = \begin{bmatrix} W_{11} & \dots & W_{1k} & \dots & W_{1S} \\ & \dots & & & \\ W_{C1} & \dots & W_{Ck} & \dots & W_{CS} \\ & & & \dots & \\ W_{N_{\text{class}}1} & \dots & W_{N_{\text{class}}k} & \dots & k_{N_{\text{class}}S} \end{bmatrix}, \tag{24}$$

where W_{Ck} is the weight of the kth descriptor of the Cth class. The weight matrix will be used to improve the performance of matching methods. In the following sections, two matching methods are described, where the contribution of weights to the final results is noticeable.

4.2. First weight-based matching algorithm: "weight method 1" (WM1)

Let Q be a query model and A a model from the database to be compared with Q. The model descriptors are compared in pairs using the following formula ($L1$-distance):

$$L1 = \sqrt{\sum_{k=1}^{S} W_{Ck} \left| D^Q(k) - D^A(k) \right|}, \tag{25}$$

where $D^Q(k)$ is the kth descriptor of the query model Q and $D^A(k)$ is the kth descriptor of the model A that belongs to class C. In this method, both $D^Q(k)$ and $D^A(k)$ descriptors are assigned the weight W_{Ck} of class C.

4.3. Second weight-based matching algorithm: "weight method 2" (WM2)

Let now A^i ($i = 1,\dots,N_{\text{total}}$) be a model of the database, where N_{total} is the total number of models in the database. In this method, the $L1$-distance between Q and A^i models is calculated. However, in this case, $\mathbf{D}^Q(k)$ and $\mathbf{D}^{A^i}(k)$ descriptors are not assigned the same weights.

Specifically, for a query Q, N_{class} different cases are considered. For the nth case ($n = 1,\dots,N_{\text{class}}$) it is assumed that the query Q belongs to class n, so that its $\mathbf{D}^Q(k)$ descriptor vector is assigned the corresponding $\mathbf{W}_n(k)$ weight vector (nth raw of the weight matrix). For each case n, for each pair of Q and A^i models, the $L1$-distance is calculated according to the following formula:

$$L1^i_n = \sqrt{\sum_{k=1}^{S} \left| W_{nk} D^Q(k) - W_{Ck} D^{A^i}(k) \right|}, \tag{26}$$

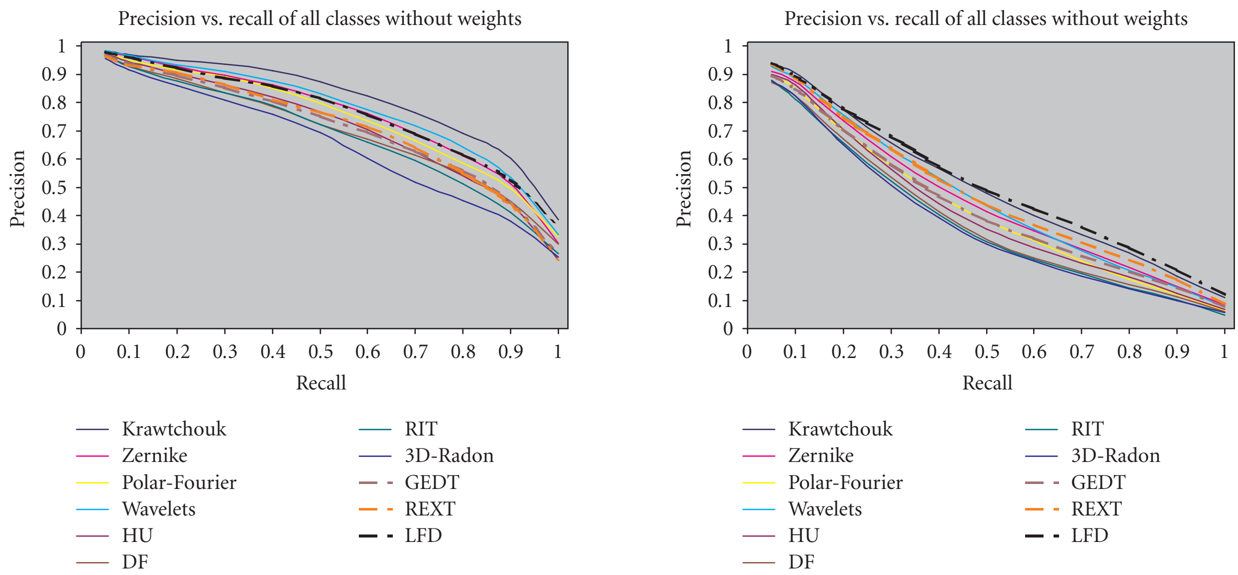
where $n = 1,\dots,N_{\text{class}}$ and $i = 1,\dots,N_{\text{total}}$. In all N_{class} cases, the model A^i is assigned the same $\mathbf{W}_C(k)$ weight vector (Cth raw of the weight matrix).

The final matching between Q and A^i is achieved by choosing only one case n (out of N_{class}). The query Q is assigned the same weights $\mathbf{W}_n(k)$ for all $L1^i$ distances. The selection of the optimal case n is based on the following procedure.

For each case n, all $L1^i_n$ distances between the query Q and the models A^i of the database ($i = 1,\dots,N_{\text{total}}$) are sorted in ascending order. In order to evaluate the homogeneity of the retrieved results at the first positions of the ranking list, the popular "Gini" index $I(n)$ [28] is used, as a measure of impurity. The smaller the Gini index, the lower the heterogeneity of the retrieved results:

$$I(n) = 1 - \sum_{C=1}^{N_{\text{class}}} p_C^2, \tag{27}$$

where p_C is the fraction of models retrieved at the first k positions of the ranking list that belong to class C, divided with k. Notice that $I(n) = 0$ if all the retrieved models belong to the same class. The case n (out of N_{class}) with the lowest Gini impurity index is used for the final matching between Q and A^i models (26).



(a) (b)

FIGURE 4: Precision-recall curves diagram using the new database (a) and the Princeton database (b).

If $T > 1$ lowest impurity indices are encountered, a second measure is taken into account.

Let $n_i = \arg\min I(n)$, $i = 1, \ldots, T$. For each n_i, let the majority of the models retrieved at the first k positions of the ranking list belong to class C_i. The number M_{n_i} of the models of category C_i, from the first position to the position that a model of a category other than C_i occurs, is calculated for each n_i. The fraction M_{n_i}/N_{C_i}, where N_{C_i} is the total number of models in class C_i, is the second measure for the selection of the best value of n_i. The value leading to the largest value of the fraction above is the one selected for the final matching, that is, $n_i = \arg\max\{M_{n_i}/N_{C_i}\}$.

5. EXPERIMENTAL RESULTS

The proposed method was tested using two different databases. The first one, formed in Princeton University [29] consists of 907 3D models classified into 35 main categories. Most are further classified into subcategories, forming 92 categories in total. This classification reflects primarily the function of each object and secondarily its form [30]. The second one was compiled from the Internet by us, it consists of 544 3D models from different categories and was also used in [31]. The VRML models were collected from the World Wide Web so as to form 13 more balanced categories: 27 animals, 17 spheroid objects, 64 conventional airplanes, 55 delta airplanes, 54 helicopters, 48 cars, 12 motorcycles, 10 tubes, 14 couches, 42 chairs, 45 fish, 53 humans, and 103 other models. This choice reflects primarily the shape of each object and secondarily its function. The average numbers of vertices and triangles of the models in the new database are 5080 and 7061, respectively.

To evaluate the proposed method, each 3D model was used as a query object. Our results were compared with those of the following methods, which have been reported [29] as the best-known shape matching methods that produce the best retrieval results.

(i) *Gaussian Euclidean distance transform (GEDT)*: it is based on the comparison of a 3D function, whose value at each point is given by composition of a Gaussian with the Euclidean distance transform of the surface [12].

(ii) *Light field descriptor (LFD)*: uses a representation of a model as a collection of images rendered from uniformly sampled positions on a view sphere. The distance between two descriptors is defined as the minimum $L1$-difference, taken over all rotations and all pairings of vertices on two dodecahedra [7].

(iii) *Radialized spherical extent function (REXT)*: uses a collection of spherical functions giving the maximal distance from center of mass as a function of spherical angle and radius [32].

It is noted that we did not implement the above methods. All executables were taken from the home pages of the authors of [7, 12, 32].

The retrieval performance was evaluated in terms of "precision" and "recall," where precision is the proportion of the retrieved models that are relevant to the query and recall is the proportion of relevant models in the entire database that are retrieved in the query.

Experimental results have shown that the following descriptor vectors should be selected, for achieving best performance, in the case of multiple descriptor vector extraction: $\text{FT} = \{\text{FT}_{00}, \text{FT}_{01}, \text{FT}_{10}\}$, $\text{HU} = \{\text{HU}_0, \text{HU}_3\}$, $Z = \{Z_{00}, Z_{11}, Z_{20}, Z_{31}\}$, $K = \{K_{00}, K_{01}, K_{02}, K_{11}\}$, $\text{WT} = \{\text{WT}_{00}, \text{WT}_{01}, \text{WT}_{10}, \text{WT}_{11}\}$, and $\text{DF} = \{\text{DF}_2, \text{DF}_4\}$.

Figure 4(a) contains a numerical precision versus recall comparison with the aforementioned methods using the new

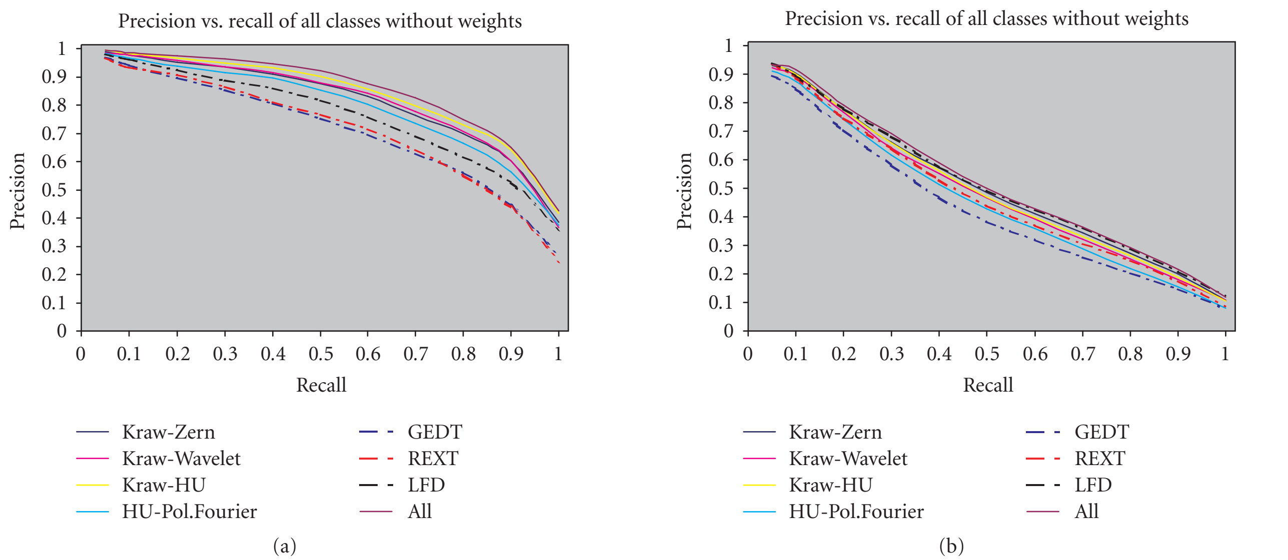


Figure 5: Precision-recall curves diagram: some of the best descriptor vector combinations, using the new database (a) and the Princeton database (b).

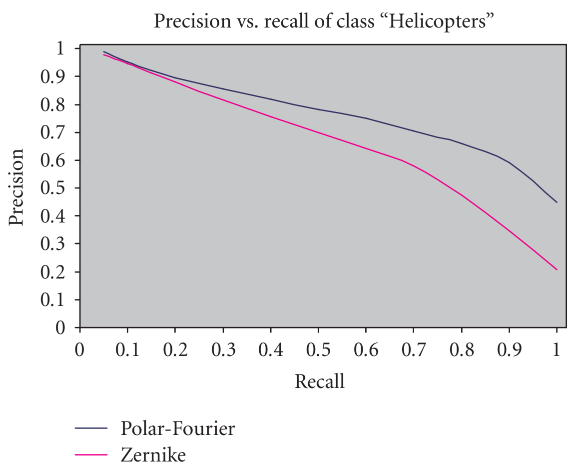


Figure 6: Comparison of the efficiency of the Polar-Fourier-based descriptor vector against the Zernike moments-based descriptor vector for a class of the new database.

database. It is clear that the proposed method outperforms all others using the integrated descriptor vector and calculating the percentage factors for each descriptor vector. Additionally, other descriptor vectors produced by Krawtchouk moments, Zernike moments, the Polar wavelet transform, the Polar-Fourier transform, and the HU moments outperform or are competitive with the other known state-of-the-art methods. Figure 4(b) illustrates the results using the Princeton database. In this database, the LFD method provides the best retrieval precision, and only the descriptor vectors based on the Krawtchouk moments and on the Zernike moments are competitive.

In Figure 5, some of the best combinations which significantly improve the retrieval performance of the proposed method are shown. The retrieval performance is improved due to the fact that a single descriptor vector does not outperform all the others in all different classes, thus using the percentage factors (see Section 4) we can take advantage of the real discriminative power of each descriptor vector per each different class. An example is illustrated in Figure 6 where the descriptor vector based on Polar-Fourier transform is seen to outperform the descriptor vector based on Zernike moments in class "helicopters" of the new database. However, the overall retrieval performance of the descriptor vector based on Zernike moments is better (Figure 4(a)). Figure 5 illustrates the results obtained using all the descriptor vectors and their percentage factors. It is clear that the proposed method outperforms all known methods in both databases. However, this procedure is time consuming, thus, simpler alternatives such as the combination *Krawtchouk-Zernike*, or the combination *Krawtchouk-Hu*, can be used instead, with very good results.

Figure 7 depicts the precision-recall diagram using the "weight method 1" (WM1) using the new database and the Princeton database. It is obvious that the retrieval results were improved significantly. In Figure 8 some of the best combinations which significantly improve the retrieval performance of the proposed method are shown.

Figure 9 illustrates the precision-recall diagram using the "weight method 2" (WM2) using the new database and the Princeton database. The results are impressive, especially for

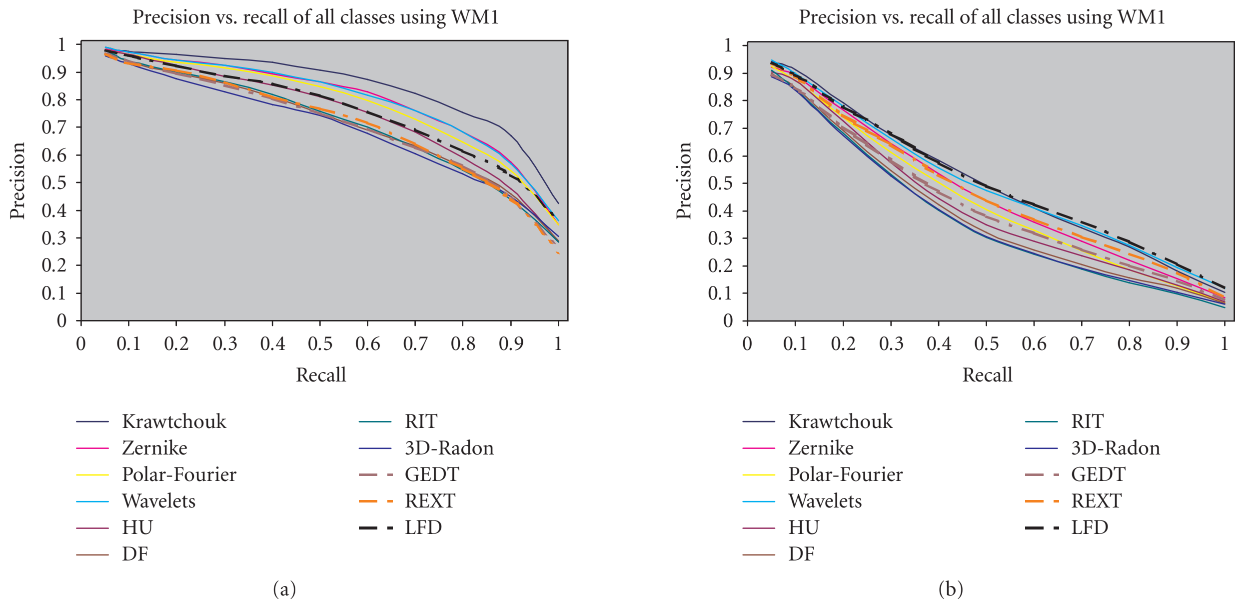


Figure 7: Precision-recall curves diagram using the weight method 1 for the new database (a) and for the Princeton database (b).

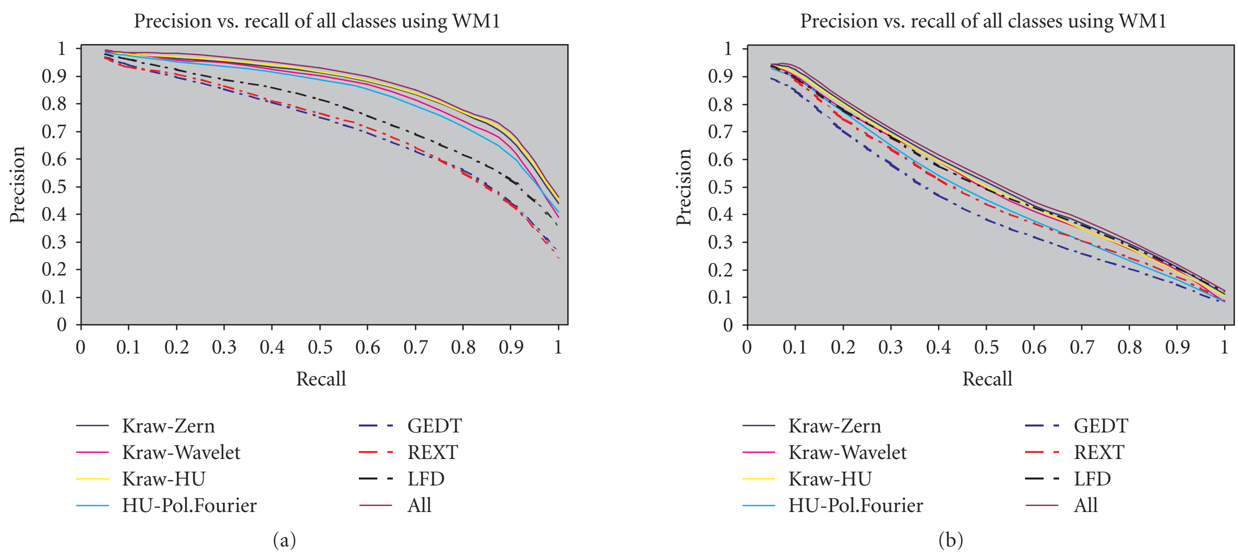


Figure 8: Precision-recall curves diagram some of the best descriptor vector combinations, using the weight method 1 for the new database (a) and for the Princeton database (b)

the new database where all of the proposed descriptor vectors outperform the others.

In Figure 10 some of the best combinations which significantly improve the retrieval performance of the proposed method are depicted.

Figure 11 illustrates the results of the experiments performed in the new database using different dimensionality for the RIT-based descriptor vector changing the number L of the harmonics of the spherical Fourier transform. It is obvious that an increase in precision is observed if the number of spherical harmonics L increases from $L = 21$ to $L = 26$. However, there was no commensurate modification in precision for values of L higher than 26, while the time needed for the extraction of the descriptor vectors as well as for carrying out the matching procedure increased sharply.

6. CONCLUSIONS

In this paper a novel framework for 3D model search and retrieval was proposed. A set of functionals is applied to

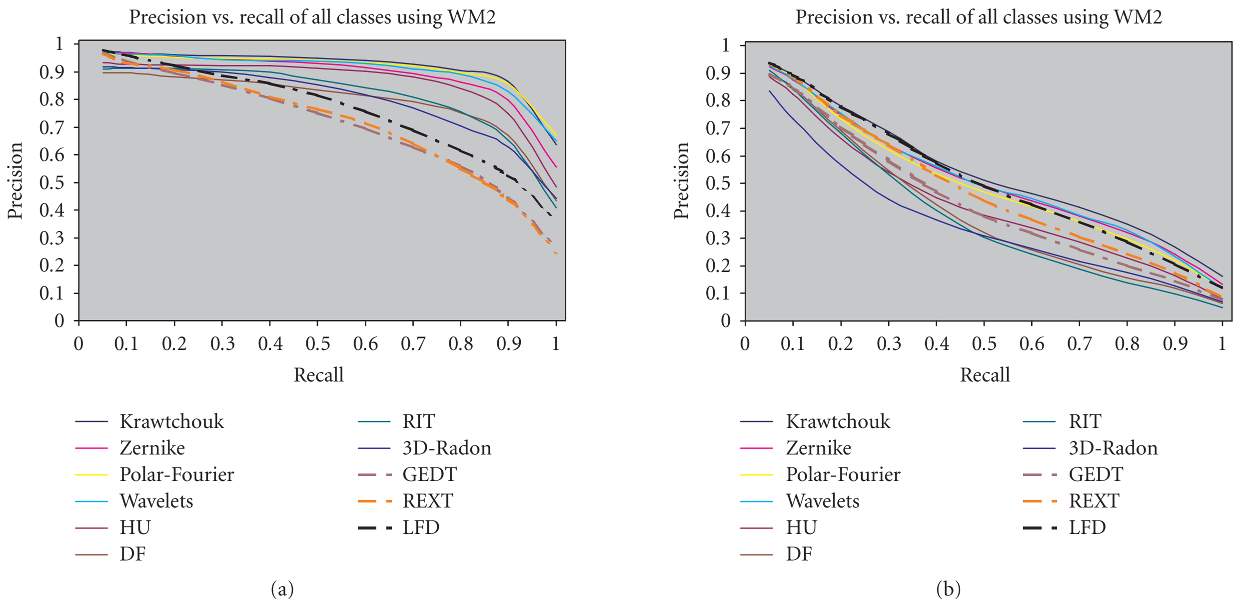


Figure 9: Precision-recall curves diagram using the weight method 2 for the new database (a) and for the Princeton database (b).

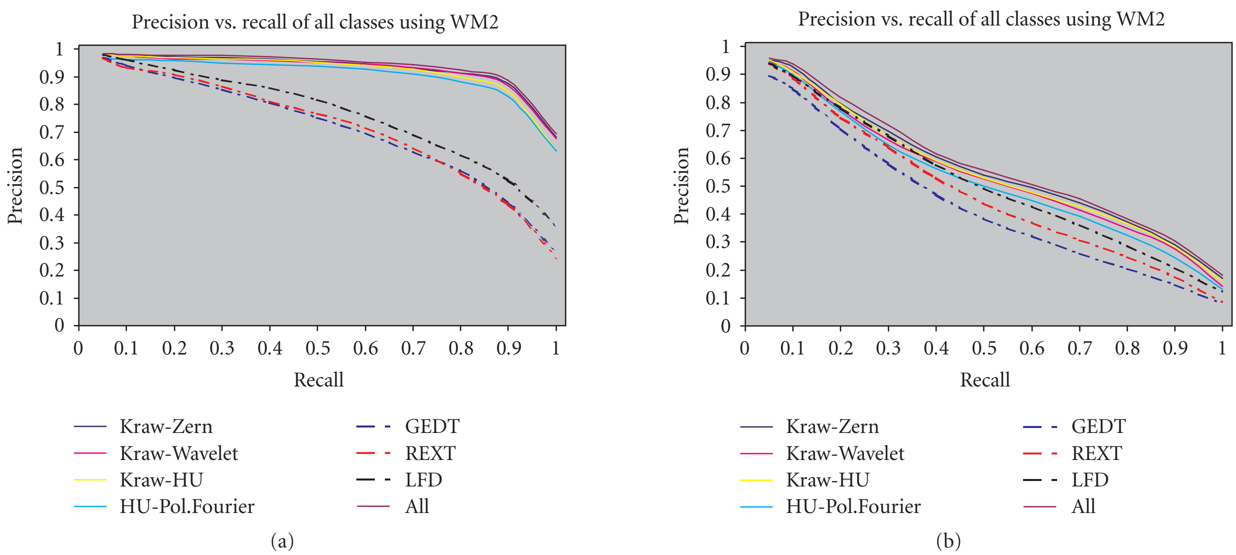


Figure 10: Precision-recall curves diagram some of the best descriptor vector combinations, using the weight method 2 for the new database (a) and for the Princeton database (b).

the volume of the 3D model producing a new domain of concentric spheres. In this new domain, a new set of functionals is applied, resulting in a completely rotation invariant descriptor vector, which is used for 3D model matching. Further, a novel technique, where weights are assigned to the descriptors, is introduced, which improves significantly the retrieval results. Experiments were performed using two different databases and the results of the proposed method were compared with those of the best known retrieval methods in the literature. The results show clearly that the proposed method outperforms all others in terms of precision recall.

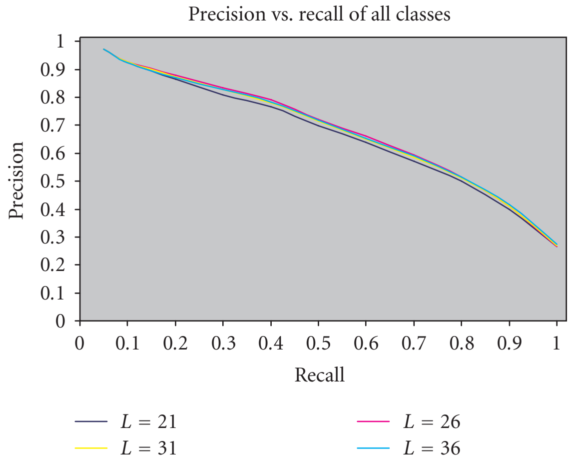


Figure 11: Comparison of the efficiency of RIT-based descriptor vectors using different dimensionality, in terms of precision-recall diagram using the new database.

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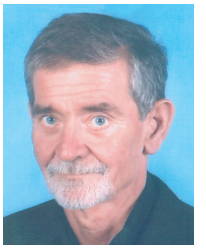

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on Human-Activity Analysis in Multimedia Data

Call for Papers

Many important applications of multimedia revolve around the detection of humans and the interpretation of human behavior, for example, surveillance and intrusion detection, automatic analysis of sports videos, broadcasts, movies, ambient assisted living applications, video conferencing applications, and so forth. Success in this task requires the integration of various data modalities including video, audio, and associated text, and a host of methods from the field of machine learning. Additionally, the computational efficiency of the resulting algorithms is critical since the amount of data to be processed in videos is typically large and real-time systems are required for practical implementations.

Recently, there have been several special issues on the human detection and human-activity analysis in video. The emphasis has been on the use of video data only. This special issue is concerned with contributions that rely on the use of multimedia information, that is, audio, video, and, if available, the associated text information.

Papers on the following and related topics are solicited:

- Video characterization, classification, and semantic annotation using both audio and video, and text (if available).
- Video indexing and retrieval using multimedia information.
- Segmentation of broadcast and sport videos based on audio and video.
- Detection of speaker turns and speaker clustering in broadcast video.
- Separation of speech and music/jingles in broadcast videos by taking advantage of multimedia information.
- Video conferencing applications taking advantage of both audio and video.
- Human mood detection, and classification of interactivity in duplexed multimedia signals as in conversations.
- Human computer interaction, ubiquitous computing using multimedia.
- Intelligent audio-video surveillance and other security-related applications.

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Special Issue on

Signal Processing for Location Estimation and Tracking in Wireless Environments

Call for Papers

In recent years, the proliferation of mobile computing devices and wireless technologies has fostered a growing interest in location-aware systems and services. The availability of location information on objects and human beings is critical in many military and civilian applications such as emergency call services, tracking of valuable assets, monitoring individuals with special needs in assisted living facilities, location-assisted gaming (e.g., Geocaching), etc.

Existing positioning systems can be categorized based on whether they are intended for indoor or outdoor applications. Within both of these application areas, there are two major categories of position estimation techniques, as discussed below.

- *Geometric techniques*–Position is estimated by exploiting time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA) or other information derived from the relationship between the geometry of an array of receivers and the modeled propagation characteristics of the transmitted signal.
- *Mapping approaches*–Position is estimated based on comparison of local measurements to a "map" of expected distribution of the measured values. For example, in a wireless LAN application, received signal strength (RSS) might be observed either at the location of the client or at a remote reference point. Mapping approaches are also known as location fingerprinting.

Although geometric approaches have the potential to achieve higher precision than mapping approaches, they generally require direct-path signal reception or accurate environmental information at the receiver and often perform poorly in complex multipath environments. On the other hand, estimation accuracy of mapping approaches is limited by both the accuracy of the reference map and the accuracy of observed measurements. Furthermore, frequent and extensive site-survey measurements are often needed to accommodate the time varying nature of wireless channels, structural changes in the environment, and upgrades of wireless infrastructure.

In addition to snapshots of AOA, TOA, TDOA or RSS measurements, motion models or prior knowledge of structural constraints can often be used to enhance location estimation accuracy for mobile objects by "tracking" location estimates over time. Trackers that integrate such information into the computation of location estimates are generally implemented using techniques such as Kalman filters, particle filters, Markov chain Monte Carlo methods, etc.

The purpose of the proposed special issue is to present a comprehensive picture of both the current state of the art and emerging technologies in signal processing for location estimation and tracking in wireless environments. Papers are solicited on all related aspects from the point of view of both theory and practice. Submitted articles must be previously unpublished and not concurrently submitted for publication on other journals.

Topics of interest include (but are not limited to):

- Received signal strength (RSS), angle-of-arrival (AOA), and time-based location estimation
- Ultrawideband (UWB) location estimation
- Bayesian location estimation and tracking
- Pattern recognition and learning theory approaches to location estimation
- Applications of expectation-maximization (EM) and Markov chain Monte Carlo (MCMC) techniques
- Applications of electromagnetic propagation modeling to location estimation
- Mitigation of errors due to non-line-of-sight propagation
- System design and configuration
- Performance evaluation, performance bounds, and statistical analysis

- Computational complexity and distributed computation
- Distributed location estimation
- Synchronization issues
- Testbed implementation, real-world deployment, and measurement

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Special Issue on Track Before Detect Algorithms

Call for Papers

Seamless detection and tracking schemes are able to integrate unthresholded (or below target detection threshold) multiple sensor responses over time to detect and track targets in low signal-to-noise ratio (SNR) and high clutter scenarios. These schemes, also called "track-before-detect (TBD)" algorithms are especially suitable for tracking weak targets that would only very rarely cross a standard detection threshold as applied at the sensor level.

Thresholding sensor responses result in a loss of information. Keeping this information allows some TBD approaches to deal with the classical data association problem effectively in high clutter and low SNR situations. For example, in detection scenarios with simultaneous activation/illumination from different signal sources this feature allows the application of triangulation techniques, where in the case of contact tracking approaches essential information about weak targets would often be lost because these targets did not produce signals that cross the normal detection threshold. Extending this example to a multi-sensor network scenario, a TBD algorithm that can use unthresholded (or below threshold) data has the potential to show improved performance compared to an algorithm that relies on thresholded data. In low SNR situations, this can substantially increase performance particularly in the case of a dense multi-target scenario.

Naturally, TBD algorithms consume high computational processing power: An efficient realization and coding of the TBD scheme is mandatory.

Another issue that arises when using the TBD scheme is the quality of the sensor model: Practical experience with thresholded data shows that a coarser modelling of the likelihood function might be sufficient and often leads to robust algorithms. How much have these sensor models to be improved in order to allow the TBD algorithms to exploit the information provided with the unthresholded data?

TBD algorithms that are well known to the tracking community are the likelihood ratio detection and tracking (LRDT), maximum likelihood probabilistic data association (MLPDA), maximum likelihood probabilistic multihypothesis tracking (MLPMHT), Houghtransform based methods and dynamic programming techniques; also related are the probability hypothesis density (PHD), the histogram probabilistic multi- hypothesis tracking (H-PMHT) algorithms, and, of course, various particle filter approaches. Some of these algorithms are capable of tracking extended targets and performing signal estimation in multi-sensor measurements.

The aim of this special issue is to focus on recent developments in this expanding research area. The special issue will focus on one hand on the development and comparison of algorithmic approaches, and on the other hand on their currently ever-widening range of applications such as in active or passive surveillance scenarios (e.g. for object tracking and classification with image and video based sensors, or scenarios involving chemical, electromagnetic and acoustic sensors). Special interest lies in multi-sensor data fusion and/or multi-target tracking applications.

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Special Issue on

Advanced Signal Processing and Pattern Recognition Methods for Biometrics

Call for Papers

Biometric identification has established itself as a very important research area primarily due to the pronounced need for more reliable and secure authentication architectures in several civilian and commercial applications. The recent integration of biometrics in large-scale authentication systems such as border control operations has further underscored the importance of conducting systematic research in biometrics. Despite the tremendous progress made over the past few years, biometric systems still have to reckon with a number of problems, which illustrate the importance of developing new biometric processing algorithms as well as the consideration of novel data acquisition techniques. Undoubtedly, the simultaneous use of several biometrics would improve the accuracy of an identification system. For example the use of palmprints can boost the performance of hand geometry systems. Therefore, the development of biometric fusion schemes is an important area of study. Topics related to the correlation between biometric traits, diversity measures for comparing multiple algorithms, incorporation of multiple quality measures, and so forth need to be studied in more detail in the context of multibiometrics systems. Issues related to the individuality of traits and the scalability of biometric systems also require further research. The possibility of using biometric information to generate cryptographic keys is also an emerging area of study. Thus, there is a definite need for advanced signal processing, computer vision, and pattern recognition techniques to bring the current biometric systems to maturity and allow for their large-scale deployment.

This special issue aims to focus on emerging biometric technologies and comprehensively cover their system, processing, and application aspects. Submitted articles must not have been previously published and must not be currently submitted for publication elsewhere. Topics of interest include, but are not limited to, the following:

- Fusion of biometrics
- Analysis of facial/iris/palm/fingerprint/hand images
- Unobtrusive capturing and extraction of biometric information from images/video
- Biometric identification systems based on face/iris/palm/fingerprint/voice/gait/signature
- Emerging biometrics: ear, teeth, ground reaction force, ECG, retina, skin, DNA
- Biometric systems based on 3D information
- User-specific parameterization
- Biometric individuality
- Biometric cryptosystems
- Quality measure of biometrics data
- Sensor interoperability
- Performance evaluation and statistical analysis

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Special Issue on Signal Processing for Data Converters

Call for Papers

Data converters (ADCs and DACs) ultimately limit the performance of today's communication systems. New concepts for high-speed, high-resolution, and power-aware converters are therefore required, which also lead to an increased demand for high-speed and high-resolution sampling systems in the measurement industry. Present converter technologies operate on their limits, since the downscaling of IC technologies to deep submicron technologies makes their design increasingly difficult. Fortunately, downscaling of IC technologies allows for using additional chip area for digital signal processing algorithms with hardly any additional costs. Therefore, one can use more elaborate signal processing algorithms to improve the conversion quality, to realize new converter architectures and technologies, or to relax the requirements on the analog design. Pipelined ADCs constitute just one example of converter technology where signal processing algorithms are already extensively used. However, time-interleaved converters and their generalizations, including hybrid filter bank-based converters and parallel sigma-delta-based converters, are the next candidates for digitally enhanced converter technologies, where advanced signal processing is essential. Accurate models constitute one foundation of digital corrected data converters. Generating and verifying such models is a complex and time-consuming process that demands high-performance instrumentation in conjunction with sophisticated software defined measurements.

The aim of this special issue is to bring forward recent developments on signal processing methods for data converters. It includes design, analysis, and implementation of enhancement algorithms as well as signal processing aspects of new converter topologies and sampling strategies. Further, it includes design, analysis, and implementation of software defined measurements for characterization and modeling of data converters.

Topics of interest include (but are not limited to):

- Analysis, design, and implementation of digital algorithms for data converters
- Analysis and modeling of novel converter topologies and their signal processing aspects
- Digital calibration of data converters
- Error identification and correction in time-interleaved ADCs and their generalizations
- Signal processing for application-specific data converters (communication systems, measurement systems, etc.)
- New sampling strategies
- Sampling theory for data converters
- Signal processing algorithms for data converter testing
- Influence of technology scaling on data converters and their design
- Behavioral models for converter characterization
- Instrumentation and software defined measurements for converter characterization

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Special Issue on Distributed Space-Time Systems

Call for Papers

Diversity is a powerful technique to mitigate channel fading and to improve robustness to cochannel interference in a wireless network. Space-time wireless systems traditionally use multiple colocated antennas at the transmitter and receiver along with appropriate signal design (also known as space-time coding) to realize spatial diversity in the link. Typically this diversity can augment any frequency and time diversity available to the receiver. Multiple antennas also offer the ability to use spatial multiplexing to dramatically increase the data rate.

A recent development in this area aims at dispensing with the need for colocated antennas. Popularly known as the cooperative diversity technique, this uses the antennas at multiple user terminals in a network in the form of a virtual antenna array to realize spatial diversity in a distributed fashion. Such techniques create new challenges in the design of wireless systems.

The purpose of this call for papers is to address some of these challenges such as new protocols for cooperative diversity, cross-layer design, cooperative multiplexing, space-time coding for distributed antennas, cooperative channel estimation and equalization, selecting the right users for participating in a cooperative network, modulation specific issues like OFDMA and CDMA, and distributed space-time processing for sensor networks.

Papers on the following and related topics are solicited for this special issue:

- New protocols for cooperative diversity systems
- Cross-layer protocol design
- Signal design for distributed space-time systems
- Cooperative channel estimation and equalization
- Cooperative MIMO systems
- Distributed space-time processing for sensor networks
- Power allocation in distributed space-time systems
- Fast algorithms and efficient architectures for virtual MIMO receivers
- Energy efficient relay network architectures

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Special Issue on

Cooperative Localization in Wireless Ad Hoc and Sensor Networks

Call for Papers

One of the major requirements for most applications based on wireless ad hoc and sensor networks is accurate node localization. In fact, sensed data without position information is often less useful.

Due to several factors (e.g., cost, size, power), only a small fraction of nodes obtain the position information of the anchor nodes. In this case, a node has to estimate its position without a direct interaction with anchor nodes and a cooperation between nodes is needed in a multihop fashion. In some applications, none of the nodes are aware of their absolute position (anchor-free) and only relative coordinates are estimated instead.

Most works reported in the literature have studied cooperative localization with the emphasis on algorithms. However, very few works give emphasis on the localization as estimation or on the investigation of fundamental performance limits as well as on experimental activities. In particular, the fundamental performance limits of multihop and anchor-free positioning in the presence of unreliable measurements are not yet well established. The knowledge of such limits can also help in the design and comparison of new low-complexity and distributed localization algorithms. Thus, measurement campaigns in the context of cooperative localization to validate the algorithms as well as to derive statistical models are very valuable.

The goal of this special issue is to bring together contributions from signal processing, communications and related communities, with particular focus on signal processing, new algorithm design methodologies, and fundamental limitations of cooperative localization systems. Papers on the following and related topics are solicited:

- anchor-based and anchor-free distributed and cooperative localization algorithms that can cope with unreliable range measurements
- derivation of fundamental limits in multihop and anchor-free localization scenarios
- new localization algorithms design methodologies based, for example, on statistical inference and factor graphs
- low-complexity and energy-efficient distributed localization algorithms
- distributed ranging and time synchronization techniques
- measurement campaigns and statistical channel modeling
- algorithm convergence issues
- UWB systems
- localization through multiple-antenna systems
- experimental results

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Special Issue on Multimedia over Wireless Networks

Call for Papers

Scope

In recent years there has been a tremendous increase in demand for multimedia delivered over wireless networks. The design and capabilities of the mobile devices and the services being offered reflect the increase in multimedia usage in the wireless setting. Applications that are in the process of becoming essential to users include video telephony, gaming, or TV broadcasting. This trend creates great opportunities for identifying new wireless multimedia applications, and for developing advanced systems and algorithms to support these applications. Given the nature of the channel and of the mobile devices, issues such as scalability, error resiliency, and energy efficiency are of great importance in applications involving multimedia transmission over wireless networks.

The papers in this issue will focus on state-of-the-art research on all aspects of wireless multimedia communications. Papers showing significant contributions are solicited on topics including but are not limited to:

- Error resilience and error concealment algorithms
- Rate control for wireless multimedia coding
- Scalable coding and transmission
- Joint source-channel coding
- Joint optimization of power consumption and rate-distortion performance
- Wireless multimedia traffic modeling
- Wireless multimedia streaming
- Wireless multimedia coding
- QoS for wireless multimedia applications
- Distributed multimedia coding

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Special Issue on

Distributed Signal Processing Techniques for Wireless Sensor Networks

Call for Papers

Recent advances in hardware and wireless communications technologies have made possible the design of low-cost, low-power, multifunctional sensor devices. When deployed in a large number across a geographical area, these sensor devices collaborate among themselves to create a network for distributed sensing and automated information gathering, processing, and communication. Wireless sensor networks are a special case of wireless ad hoc networks that assume a multihop communication framework with no infrastructure, where the sensor devices cooperate to convey information from a source to a destination. This revolutionary technology will present a huge impact on a broad range of applications: monitoring the health status of humans, animals, plants, and civil-engineering structures, control and instrumentation of industrial machines and home appliances, energy conservation, security, detection of chemical and biological leaks. The upcoming years will very likely witness a growing demand for intelligent sensor systems that will be networked with wireless local area networks (WLANs) and Internet for increased functionality and performance.

In general, the design of wireless sensor networks is subject to the following requirements:

- low energy consumption, which is manifested in minimal energy expenditure in each sensor node and efficient usage of power-saving sleep/wake-up modes
- scalability with the increase in the number of sensors with the goal to extract information from noisy spatiotemporal measurements collected at the nodes
- broadcast communication paradigm and the increased possibility of packet collisions and congestions
- absence of centralized communication infrastructure
- possibility of frequent node failures and network topology changes

The goal of this special issue is to present the state-of-the-artresults and emerging signal processing approaches for wireless sensor networks that can cope with the above-mentioned challenges. Submitted articles must not have been previously published and must not be currently submitted for publication elsewhere. Topics of interest include the following:

- distributed estimation, detection, inference, and learning algorithms
- clock and carrier synchronization techniques
- design of distributed modulation techniques
- distributed power control algorithms
- performance bounds and statistical analysis

Due to the existence of a concurrent call for proposals, papers dealing with localization and tracking applications will not be accepted.

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Special Issue on MIMO Transmission with Limited Feedback

Call for Papers

During the past decade, multiple-antenna transmission (MIMO) systems have matured. However, when comparing their *potential* capacities with their *achieved* throughputs, we notice large gaps. The price for the MIMO advantages is implementation complexity and the use of specific signal processing tools that cannot be directly inferred from one-to-one (i.e. single-channel) systems. For instance, water-filling does not seem feasible due to the large amount of required feedback information. State-of-the-art standards like 3GPP and WiMax support only very limited feedback. Nevertheless, adaptive modulation and coding (AMC) schemes, selective space-time coding, as well as antenna selection have shown that significant improvements are achievable even with very limited feedback. In this setting, MIMO-OFDM schemes are of central interest to industry and academia. For instance, an important challenge is to find an adequate representation of the MIMO channel's quality—independently of the system architecture and signal processing techniques currently available. A proper labeling or characterization of the MIMO channel quality regardless of the spatial processing to be used enables deciding on the reception or transmission strategy to use (e.g. with or without channel state information, to optimize diversity or rate, etc.) and, thus, on the amount of feedback that is required in transmission.

MIMO transmission can be point-to-point or distributed, in fact, when looking not just into the physical layer, but also into the link layer, feedback load is especially critical in multiuser MIMO systems because of its much higher number of degrees of freedom. Opportunistic scheduling strategies have been developed which (more or less heuristically) take into account the requirements on QoS.

This special issue focuses on such transmission systems with limited feedback and provides an overview of the state of the art.

Topics of interest include (but are not limited to):

- Adaptive modulation and coding
- Selective space-time coding
- Antenna and beam selection
- Adaptive beamforming techniques
- Codebook selection for CSI feedback
- Rate distortion for feedback systems
- Approximate water-filling techniques
- Feedback in highly mobile environments
- MIMO with statistical feedback
- Nonlinear/adaptive MIMO precoding
- Fundamental limits on performance and robustness
- Opportunistic schemes
- MIMO and QoS diversity
- Inclusion of MIMO concepts in wireless standards
- Feedback in MIMO-OFDM and OFDMA schemes
- Cross-layer approaches to multiuser MIMO scheduling

Authors should follow the EURASIP JASP manuscript format described at http://www.hindawi.com/journals/asp/. Prospective authors should submit an electronic copy of their complete manuscript through the EURASIP JASP Manuscript Tracking System at http://www.hindawi.com/mts/, according to the following timetable:

Manuscript Due	June 1, 2007
First Round of Reviews	September 1, 2007
Publication Date	December 1, 2007

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IEEE ICME 2007 Call for Papers
2007 International Conference on Multimedia & Expo (ICME)

July 2-5, 2007
Beijing International Convention Center, Beijing, China

Sponsored by: Circuits and Systems Society, Communications Society, Computer Society, and Signal Processing Society.

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IEEE International Conference on Multimedia & Expo is a major annual international conference with the objective of bringing together researchers, developers, and practitioners from academia and industry working in all areas of multimedia. ICME serves as a forum for the dissemination of state-of-the-art research, development, and implementations of multimedia systems, technologies and applications. ICME is co-sponsored by four IEEE societies including the Circuits and Systems Society, the Communications Society, the Computer Society, and the Signal Processing Society. The conference will feature world-class plenary speakers, exhibits, special sessions, tutorials, and paper presentations.

Prospective authors are invited to submit a four-page paper in double-column format including authors' names, affiliations, and a short abstract. Only electronic submissions will be accepted. Topics include but are not limited to:

- Audio, image, video processing
- Virtual reality and 3-D imaging
- Signal processing for media integration
- Multimedia communications and networking
- Multimedia security and content protection
- Multimedia human-machine interface and interaction
- Multimedia databases
- Multimedia computing systems and appliances
- Hardware and software for multimedia systems
- Multimedia standards and related issues
- Multimedia applications
- Multimedia and social media on the Internet

A number of awards will be presented to the Best Papers and Best Student Papers at the conference. Participation for special sessions and tutorial proposals are encouraged.

SCHEDULE

- Special Session Proposals Due: **December 1, 2006**
- Tutorial Proposals Due: **December 1, 2006**
- Regular Paper Submissions Due: **January 5, 2007**
- Notification of Acceptance: **March 19, 2007**
- Camera-Ready Papers Due: **April 16, 2007**

Check the conference website http://www.icme2007.org for updates.

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5th International Symposium on

Image and Signal Processing and Analysis ISPA 2007

September 27-29, 2007, Istanbul, Turkey

http://www.isispa.org

Call for Papers

The 5th International Symposium on Image and Signal Processing and Analysis (ISPA 2007) will take place in Istanbul, Turkey, from September 27-29, 2007. The scientific program of the symposium consists of invited lectures, regular papers, and posters. The aim of the symposium is to foster interaction of researchers and exchange of new ideas. Prospective authors are invited to submit their manuscripts reporting original work, as well as proposals for special sessions.

Co-Operations and Co-Sponsorships

- European Association for Signal Processing (EURASIP)
- IEEE Region 8*

Symposium Topics

A. Image and Video Processing
B. Image and Video Analysis
C. Image Formation and Reproduction
D. Signal Processing
E. Signal Analysis
F. Applications

For a detailed list of subtopics please visit ISPA 2007 web site.

Important Dates

Submission of full paper: February 15, 2007
Notification of acceptance/rejection: April 15, 2007
Submission of camera-ready papers and registration: May 15, 2007

Symposium Venue

Located in the center of the Old World, Istanbul is one of the world's great cities famous for its historical monuments and scenic beauties. It is the only city in the world which spreads over two continents: it lies at a point where Asia and Europe are separated by a narrow strait - the Bosphorus. Istanbul has been the cradle for many civilizations for over 2500 years and has a very rich history. It has been the capital of three great empires, the Roman, Byzantine and Ottoman empires, and for more than 1,600 years over 120 emperors and sultans ruled the world from here. Istanbul is the heart of Turkey with respect to entertainment, culture, education, shopping, imports and exports, tourism and the arts. The symposium will be organized in the congress center of the Bogazici University.

Paper Submission Procedure

Papers including title, author list and affiliations, figures, results, and references should not exceed six A4 pages. Detailed instructions for electronic submission are available on the ISPA web site. All papers will be subject to a peer-review process with at least two reviewers. All accepted papers will be published in the symposium proceedings in book form and on CD-ROM, which will be available through IEEE Publications Center and in IEEEXplore digital library.

Call for Special Session Proposals

Prospective organizers of special sessions are invited to send proposals to Special Session Co-Chairs, according to instructions provided on the ISPA web site. The aim of a special session is to provide an overview of the state-of-the-art and current research directions in specific fields of image and signal processing and analysis.

Best Student Paper Award

Best Student Paper Award in the amount of 300 EUR will be given to a student author. The student's name must appear first on the paper and the paper must be presented at the symposium to be eligible for the award.

* request pending

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ISSPA 2007

International Symposium on Signal Processing and its Applications

in conjunction **with the International Conference on Information Sciences, Signal Processing and their Applications**

12 – 15 February 2007, Millennium Hotel, Sharjah, U.A.E.

Call For Participation

ISSPA 2007 marks the 20th anniversary of launching the first ISSPA in 1987 in Brisbane, Australia. Since its inception, ISSPA has provided, through a series of 8 symposia, a high quality forum for engineers and scientists engaged in research and development of Signal and Image Processing theory and applications. Effective 2007, ISSPA will extend its scope to add the new track of information sciences. Hence, the intention that the previous full name of ISSPA is replaced after 2007 by the following new full name:
International Conference on Information Sciences, Signal Processing and their Applications. ISSPA is an IEEE indexed conference.

ISSPA 2007 is organized by the University of Sharjah, College of Engineering, Etisalat University College and the American University of Sharjah.

The regular technical program will run for three days along with an exhibition of signal processing and information sciences products. In addition, tutorial sessions will be held on the first day of the symposium. Presentations will be given in the following topics:

1. Filter Design Theory and Methods
2. Multirate Filtering & Wavelets
3. Adaptive Signal Processing
4. Time-Frequency/Time-Scale Analysis
5. Statistical Signal & Array Processing
6. Radar & Sonar Processing
7. Speech Processing & Recognition
8. Fractals and Chaos Signal Processing
9. Signal Processing in Communications
10. Signal processing in Networking
11. Multimedia Signal Processing
12. Nonlinear signal processing
13. Biomedical Signal and Image Processing
14. Image and Video Processing
15. Image Segmentation and Scene Analysis
16. VLSI for Signal and Image Processing
17. Cryptology, Steganography, and Digital Watermarking
18. Image indexing & retrieval
19. Soft Computing & Pattern Recognition
20. Natural Language Processing
21. Signal Processing for Bioinformatics
22. Signal Processing for Geoinformatics
23. Biometric Systems and Security
24. Machine Vision
25. Data visualization
26. Data mining
27. Sensor Networks and Sensor Fusion
28. Signal Processing and Information Sciences Education
29. Others
30. Special Sessions

Prospective authors were invited to submit ***full length*** *(four pages) papers* ***via the conference website*** *for presentation in any of the areas listed above (showing area in submission). Submission of proposals for student session, tutorials and sessions on special topics were sent to the conference secretary. All articles submitted to ISSPA 2007 are* ***peer-reviewed*** *using a* ***blind review process*** *by at least two independent reviewers.*

For more details see

www.isspa2007.org/

Important Deadlines:

Full Paper Submission:
October 14, 2006
Tutorials/Special Sessions Submission:
October 14, 2006
Notification of Acceptance:
December 3, 2006
Final Accepted Paper Submission:
December 19, 2006

Conference Secretary

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15th European Signal Processing Conference

EUSIPCO 2007

September 3-7, 2007, Poznań, Poland

Just in the centre of Europe!

European Association for Signal, Speech and Image Processing

CALL FOR PAPERS

The 2007 European Signal Processing Conference (EUSIPCO-2007) is the fifteenth in a series of conferences promoted by EURASIP, the European Association for Signal, Speech, and Image Processing. The conference will be organized by Poznań University of Technology, Faculty of Electronics and Telecommunications Chair of Multimedia Telecommunications and Microelectronics and PTETiS Society in Conference Center at Poznań International Fair.

As usual, EUSIPCO-2007 areas of interest will cover all aspects of signal processing theory and applications as listed below. Proposals for special sessions and tutorials are strongly encouraged. Accepted papers will be published in the proceedings of EUSIPCO-2007. Acceptance will be based on quality, relevance and originality.

The conference topics include:

- Audio and Electroacoustics
- Design and Implementation of Signal Processing Systems
- DSP Applications and Embedded Systems
- Emerging Technologies in Signal Processing
- Signal Processing for Communications
- Image and Multidimensional Signal Processing
- Medical Imaging
- Image and Video Analysis
- Multimedia Signal Processing
- Speech Processing and Coding
- Image, Video and Audio Compression
- Nonlinear Signal Processing
- Sensor Array and Multichannel Processing
- Signal Detection and Estimation
- Signal Processing Applications (Biology, Geophysics, Seismic, Radar, Sonar, Remote Sensing, Astronomy, Bio-informatics, Positioning, etc.)
- Signal Processing Algorithms and their Implementations in Communication Systems
- Hardware Solutions for Signal Processing
- Education on Signal Processing

Submission

Procedures to submit a paper, proposals for sessions/tutorials, can be found at www.eusipco2007.org. Submitted papers must be final, full papers, no more than five pages long all inclusive and strictly conforming to the format specified on the EUSIPCO web site.

Best Student Paper Awards

Student authors who appear as first authors in a paper may enter the student paper contest.

Important Dates (updated)

Proposals for Special Sessions and Tutorials:	December 11, 2006
Electronic submission of Full papers (4 pages A4):	February 5, 2007
Notification of Acceptance:	May 11, 2007
Submission of Camera-Ready Papers and Registration:	June 10, 2007

www.eusipco2007.org

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About EURASIP:

The European Association for Signal, Speech and Image Processing (www.eurasip.org) was founded on 1 September 1978 to: "improve communication between groups and individuals that work within the multidisciplinary, fast growing field of Signal Processing in Europe and elsewhere, and to exchange and disseminate information in the field all over the world." The association exists to promote the efforts of researchers by providing a learned and professional platform for dissemination and discussion of all aspects of signal processing. EURASIP is a non profit organization which is governed by its Administrative Committee (AdCom).

EURASIP Areas of Interest:

- Continuous and discrete time signal theory
- Applications of signal processing
- Systems and technology
- Speech communication
- Image processing and communication.

EURASIP sponsors and co-sponsors a number of conferences within Europe and the rest of the world each year. The main event is EUSIPCO (European Signal Processing Conference), which is now recognized as one of the premier signal processing conferences, attracting delegates and papers from all over the world. The venues of consecutive conferences are: Lausanne, Switzerland (1980); Erlangen, Germany (1983); Hague, the Netherlands (1986); Grenoble, France (1988); Barcelona, Spain (1990); Brussels, Belgium (1992); Edinburgh, UK (1994); Trieste, Italy (1996); Rhodes, Greece (1998); Tampere, Finland (2000); Toulouse, France (2002); Vienna, Austria (2004); Antalya, Turkey (2005); Florence, Italy (2006).
The 2007 event will be held in Poznań, Poland.

About Poznań

Poznań, a capital of Wielkopolska province, is the fifth biggest city in Poland with population of 580 000. It is halfway between Berlin and Warsaw and it is older than each one of them. Poznań is easily accessible, since it is located in central Europe and it is easy to get there both from Western and Eastern part of the continent and also the rest of the world.
Poznań-Ławica International Airport is situated only 6 km from the conference venue. There are a lot of direct flights to many of European cities. The conference site is in the city centre, in a walking distance from the main railway station, as well as a variety of hotels of various standards.
Poznań is a dynamic economic, academic, scientifical and cultural centre. Thanks to its excellent economic performance and International Fair the city is often called the economic capital of Poland. It is an excellent place for organizing conferences because it is also a centre of academic life. There are 22 universities and other institutions of higher education with over 120 000 students. Among the universities there is Poznań University of Technology one of the biggest and most recognized technical universities in Poland. Thanks to such a considerable number of students the city has got a creative and unforgettable atmosphere. An abundance of monuments and interesting places from all époques creates pleasant surroundings for social meetings after conference sessions.

www.eusipco2007.org

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IEEE

Fifth International Workshop on

Content-Based Multimedia Indexing, CBMI-2007

June 25-27, 2007
Bordeaux, France

EURASIP

CBMI 2007 CALL FOR PAPERS

Following the four successful previous events of CBMI (Toulouse 1999, Brescia 2001, Rennes 2003 and Riga 2005), the LABRI/ *University of Bordeaux* will organize the next CBMI event. CBMI'07 aims at bringing together the various communities involved in the different aspects of Content-Based Multimedia Indexing. The scientific program of CBMI'07 will include the presentation of invited plenary talks, special sessions as well as regular sessions with contributed research papers.

Authors are encouraged to submit extended papers to the Special Issue of Signal Processing: Image Communication journal, EURASIP on CBMI. Topics of interest for submissions include, but are not limited to:

- Multimedia indexing and retrieval (image, audio, video, text)
- Multimedia content extraction
- Matching and similarity search
- Construction of high level indices
- Multi-modal and cross-modal indexing
- Content-based search techniques
- Multimedia data mining
- Presentation tools
- Meta-data compression and transformation
- Handling of very large scale multimedia database
- Organisation, summarisation and browsing of multimedia documents
- Applications
- Evaluation and metrics

PAPER SUBMISSION

Prospective authors are invited to submit full papers of not more than eight (8) pages including results, figures and references. Papers will be accepted only by electronic submission through the conference web site: http://cbmi07.labri.fr/. Style files (Latex and Word) are provided for the convenience of the authors.

Submission of full paper (to be received by):	**January 25, 2007**
Notification of acceptance:	**March 10, 2007**
Submission of camera-ready papers:	**April 10, 2007**

WORKSHOP VENUE

CBMI'07 will be held in Bordeaux (France) on June 25-27, 2007

For further information: http://cbmi07.labri.fr/

MUSCLE Multimedia Understanding through Semantics, Computation and Learning

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

COST 292 Semantic Multimodal Analysis of Digital Media

INRIA

DSP2007

15th International Conference on Digital Signal Processing

July 1-4, 2007
Cardiff
Wales, UK

Call for Papers

The 15th International Conference on Digital Signal Processing (DSP 2007), the most longstanding conference in the area of DSP, organised in cooperation with the IEEE, will be held in Cardiff the capital of Wales, UK, July 1-4, 2007. DSP 2007 belongs to a series of events which had its genesis in London in 1968 and continued to Florence, Nicosia, Lemessos, and Santorini. The last meeting took place overlooking the cauldron in the bay of Fira, Santorini, in 2002. This now tranquil location was once the scene of a massive eruption which led directly to the extinction of one of Europe's oldest civilisations, the Minoans; in 2007 delegates will be brought right up to date in an area of rebirth, Cardiff Bay, the heart of Europe's youngest capital. The conference will contain a number of Special sessions organised by internationally recognised experts. The programme will also include presentations of new results in lecture and poster sessions, together with plenary sessions delivered by eminent scientists. Accepted papers will appear in IEEE Xplore.

Special Sessions

TBA

Indicative Topics of Interest

Adaptive signal processing
Array processing, radar and sonar
Biomedical signal and image processing
Bioinformatics and genomic signal processing
Blind equalization
Blind source separation
Collaborative networking
Computer vision and pattern recognition
Data fusion
Design and implementation of signal processing systems
Detection and estimation theory
Distributed Signal Processing
Image and multidimensional signal processing
Information forensics and security
Joint source-channel coding
Machine learning for signal processing
Multimedia signal processing
Multimudal signal processing
Multivariate statistical analysis
Musical signal processing
Nonlinear signal processing
Progressive data transmission
Sensor array and multichannel systems
Speech and language processing
Time-frequency and time-scale analysis

Expected dates (to be confirmed):

Electronic paper submission	February 19, 2007
Acceptance notification	April 2, 2007
Camera-ready papers	April 9, 2007
Conference	July 1-4, 2007

www.cardiff.ac.uk/dsp2007/