

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
14 April 2011 (14.04.2011)

(10) International Publication Number  
**WO 2011/042381 A1**

- (51) **International Patent Classification:**  
G06N 7/00 (2006.01)
- (21) **International Application Number:**  
PCT/EP2010/064723
- (22) **International Filing Date:**  
4 October 2010 (04.10.2010)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**  
12/574,717 7 October 2009 (07.10.2009) US
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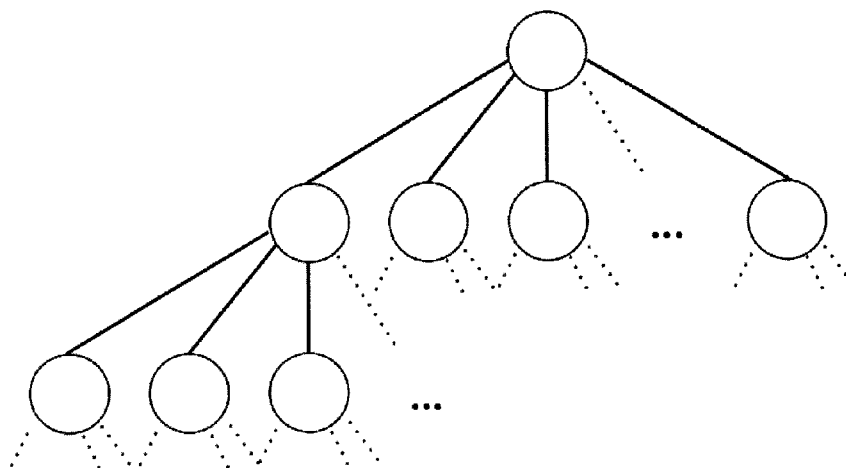
(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) **Title:** METHOD OF COMPUTING GLOBAL-TO-LOCAL METRICS FOR RECOGNITION



**Fig. 1**

(57) **Abstract:** A method of computing global-to-local metrics for recognition. Based on training examples with feature representations, the method automatically computes a local metric that varies over the space of feature representations to optimize discrimination and the performance of recognition systems. Given a set of points in an arbitrary features space, local metrics are learned in a hierarchical manner that give low distances between points of same class and high distances between points of different classes. Rather than considering a global metric, a class- based metric or a point-based metric, the proposed invention applies successive clustering to the data and associates a metric to each one of the clusters.

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# **Method of Computing Global-to-Local Metrics for Recognition**

## **Background of the invention**

The classification problem can be formulated as a verification scheme where the objective is to determine if a pair of points is positive or negative, i.e. positive if the points belong to the same class, negative otherwise. Given a set of labeled data, one can try to learn the metric that gives a discriminative distance in a given feature space that would perform the best for this task; which is to give a low distance between points of a positive pair and a high distance to points of a negative pairs. A detailed overview of this type of methods can be found in [1].

Global metric learning has become popular to improve classification algorithms, such as the K-nearest neighbors (KNN) classification algorithm [2]. It often consists of estimating the optimal covariance matrix of the Mahanlobis distance that will be used for classification. While these kinds of global metrics have shown impressive improvements for classification, they do not capture local properties in the feature space which may be relevant for complex data distributions. To overcome this difficulty, a two step approach is generally employed [3, 4]. Firstly, a global metric is learned and training points in the feature space are transformed accordingly; secondly, a local metric is estimated in the neighborhood of each transformed training point. These local metrics allow for better adaptiveness to the data but often require an heuristic choice of locality.

## **Summary of the invention**

The proposed invention is instead a hierarchical global-to-local approach, where the metric is iteratively refined and learned using the data distribution itself. The approach starts by estimating a global metric and applying the corresponding (metric) transformation to the data. Then the transformed points are clustered to obtain a set of  $K$  clusters. These two steps are recursively applied to each cluster until a termination criterion is satisfied on the cluster. such criteria can be e.g. maximal height in the tree, minimal variance of the data points in the cluster or a minimum number of data points in the cluster. This forms a tree with a metric associated to each node.

In other words, a method of computing global-to-local metrics for recognition is provided. Based on training examples with feature representations, the method automatically computes a local metric that varies over the space of feature representations to optimize discrimination and the performance of recognition systems.

Given a set of points in an arbitrary features space, local metrics are learned in a hierarchical manner that give low distances between points of same class and high distances between points of different classes. Rather than considering a global metric, a class-based metric or a point-based metric, the proposed invention applies successive clustering to the data and associates a metric to each one of the clusters.

## **Brief description of the drawings**

Figure 1 illustrates a schematic layout of a global-to-local metric

tree.

Figure 2 illustrates systems comprising of a camera and computational unit using the global-to-local metric.

## Detailed Description

Below follows a detailed description of the invention.

Given a set of labeled points  $\{x_i, i=1 \dots N\}$ , we successively apply a global metric learning algorithm on sets of hierarchically clustered points. This has the effect of forming a metric tree. For simplicity of presentation, we assume the number of clusters for each instance of the clustering algorithm to be constant and equal to  $K$ . Let  $n_{i,j}$  be the  $j^{th}$  cluster at level  $i$  and  $A_{i,j}$  be the associated metric transformation matrix. The metric is learned on the set of transformed points  $\{y_{i,j} = \prod_{k=0}^{i-1} A_{k,j/K} x_{i,j}\}$ , e.g. using, but not restricted to, the Information Theoretic Metric Learning algorithm (ITML) proposed in [5].

Before applying the clustering algorithm to a node  $n_{i,j}$ , we apply the transformation associated to the metric of that node to the points given by its parents nodes.

We can now use our metric tree to evaluate the distance between any two data points, e.g. image descriptors, face feature vectors or other feature representations. First, each point is injected in the tree and its path is recovered. In particular, we identify the last node of the tree that contain both points. The distance between the

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points is then the one obtained using the metric associated to this node, possibly compounded with the metrics of parent nodes.

In the worst case, the last common node is the root of the tree, and therefore, the distance will use the global metric. The deeper in the tree the common node is, the more local the metric is. Compared to pure local or global methods, this approach has the advantage of refining the metric in dense or complex areas, according to the termination criterion (e.g. maximum leaf size, maximum leaf variance, maximum height limit).

A possible issue with this formulation is the high dependence on the clustering boundary. Points can be close to each other and separated quite early in the clustering tree. To reduce the influence of this decision, it is possible to construct multiple metric trees and average the distances given by each one of them.

In a preferred embodiment of the invention, a method for global-to-local metric learning is presented, the method comprising the steps of;

- learning a metric tree (as may be illustrated as in Figure 1),
- classifying or comparing test data using this metric tree.

In another embodiment of the present invention, a computer program stored in a computer readable storage medium and executed in a computational unit for global-to-local metric learning comprising the steps of; learning a metric tree, classifying or comparing test points using this metric tree.

Yet another embodiment of the present invention, a system for

global-to-local metric learning and classification containing a computer program for global-to-local metric learning comprising the steps of;

- learning a metric tree,
- classifying or comparing test data using this metric tree.

In another embodiment of the present invention a system or device is used for obtaining images, analyzing, and responding to results from classification using a global-to-local metric, as may be seen in Figure 2. Such a system may include at least one image acquisition device 101 and a computational device 100.

We have described the underlying method used for the present invention together with a list of embodiments. Possible application areas for the above described invention range from, but are not restricted to, object recognition and face recognition to classification of image content.

## References

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## Claims

1. A method for global-to-local metric learning for classification and recognition comprising the steps of;
  - using a tree structure constructed with a clustering algorithm at each level, and
  - associating a metric to each one of the tree nodes.
2. The method according to claim 1, wherein said clustering algorithm is the K-means clustering.
3. The method according to claim 1 wherein said metric is a symmetric matrix obtained with the ITML algorithm.
4. The method according to claim 1 wherein said clustering algorithm uses the local metric at each node.
5. A computer program stored in a computer readable storage medium and executed in a computational unit for global-to-local metric learning according to claim 1.
6. A computer program according to claim 5, further comprising the steps of;
  - finding a relevant local metric for a given feature comparison, and;
  - using this local metric for classification or recognition.
7. A system for recognition comprising of a computer program according to claim 5 further using feature representations which are compared with a method according to claim 6.
8. A system according to claim 7 where the feature representations represent objects in images.



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9. A system according to claim 8 where the objects are faces.

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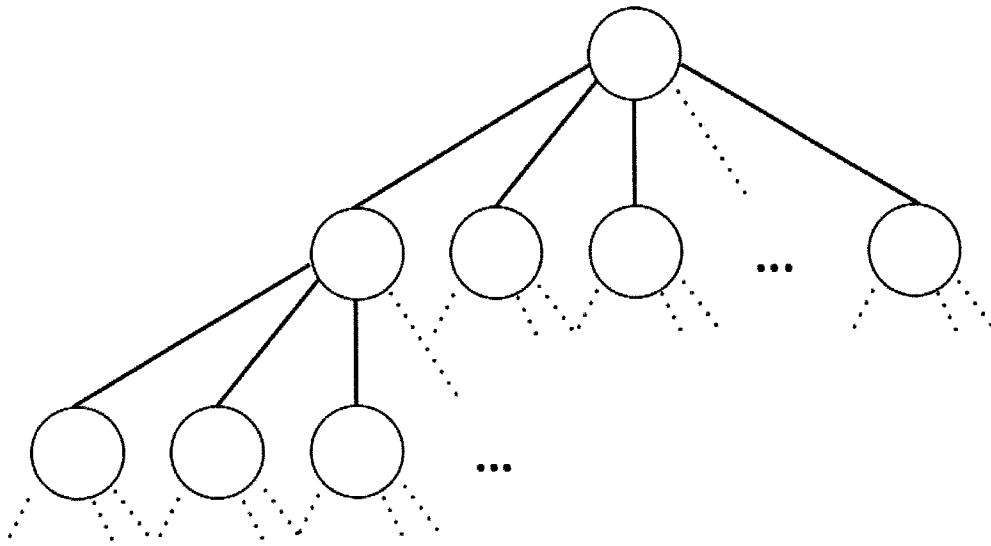


Fig. 1

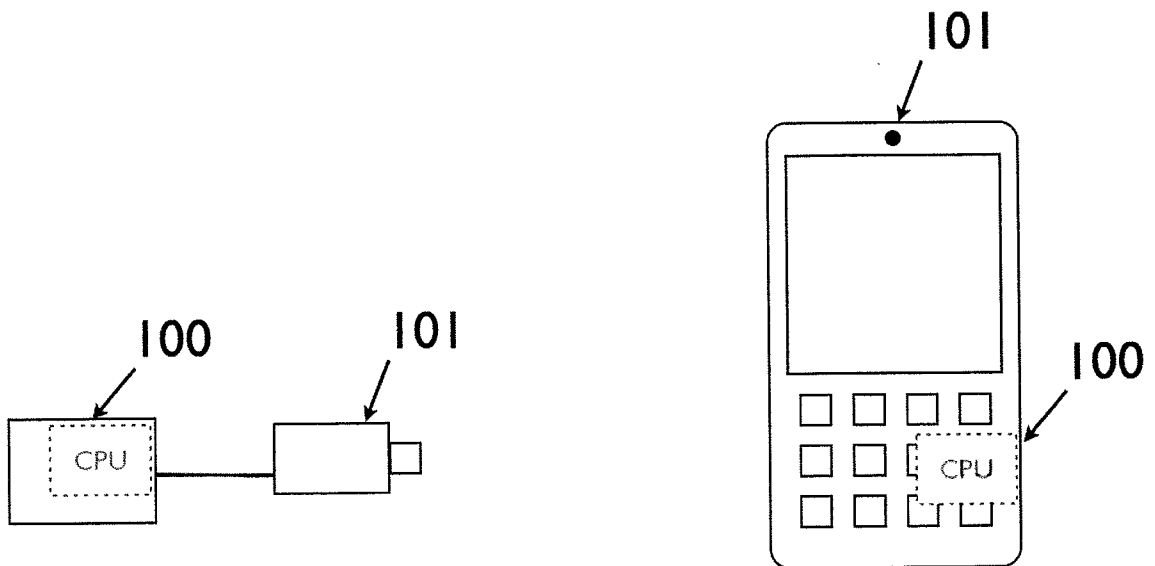


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2010/064723

A. CLASSIFICATION OF SUBJECT MATTER  
INV. G06N7/00  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
G06N G06K  
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FU Y ET AL: "Locally adaptive subspace and similarity metric learning for visual data clustering and retrieval", COMPUTER VISION AND IMAGE UNDERSTANDING, ACADEMIC PRESS, US, vol. 110, no. 3, 1 June 2008 (2008-06-01), pages 390-402, XP022652947, ISSN: 1077-3142, DOI: DOI:10.1016/J.CVIU.2007.09.017 [retrieved on 2007-12-23]	1,2,4-9
Y	page 1 - page 12 ----- -/--	3

Further documents are listed in the continuation of Box C.  See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search <b>21 January 2011</b>	Date of mailing of the international search report <b>04/02/2011</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Volkmer, Markus</b>
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2010/064723

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>Davis, Jason V. and Kulis, Brian and Jain, Prateek and Sra, Suvrit and Dhillon, Inderjit S.: "Information-theoretic metric learning",</p> <p>2007, XP002617812, DOI: 10.1145/1273496.1273523 ISBN: 978-1-59593-793-3 Retrieved from the Internet: URL:http://doi.acm.org/10.1145/1273496.1273523 [retrieved on 2001-01-21] cited in the application the whole document</p>	3
A	<p>-----</p> <p>US 2009/175509 A1 (GONION JEFF [US] ET AL) 9 July 2009 (2009-07-09) the whole document</p>	1-9
A	<p>-----</p> <p>US 2008/301133 A1 (BROWN MATTHEW [US] ET AL) 4 December 2008 (2008-12-04) the whole document</p>	1-9
A	<p>-----</p> <p>US 6 636 849 B1 (TANG YUANHUA TOM [US] ET AL) 21 October 2003 (2003-10-21) the whole document</p> <p>-----</p>	1-9

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/064723

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009175509	A1	09-07-2009	NONE
US 2008301133	A1	04-12-2008	NONE
US 6636849	B1	21-10-2003	NONE