(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 June 2012 (07.06.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/072402 Al

(51) International Patent Classification:
G06T 11/00 (2006.01) *G06T 7/40* (2006.01)

(21) International Application Number:
PCT/EP201 1/069855

(22) International Filing Date:
10 November 201 1 (10.1 1.201 1)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10306308.7 29 November 2010 (29. 11.2010) EP

(71) **Applicant** *(for all designated States except US):* **THOMSON LICENSING** [FR/FR]; 1-5 rue Jeanne d'Arc, F-92130 Issy-les-Moulineaux (FR).

(72) **Inventors; and**

(75) **Inventors/Applicants** *(for US only):* **RACAPE, Fabien** [FR/FR]; 20 rue de Brest, F-35000 Rennes (FR). **VIERON, Jerome** [FR/FR]; 9 rue Bausset-Batiment B, F-7501 5 Paris (FR). **LEFORT, Simon** [FR/FR]; 5 place de la Mairie, F-49500 Ste Gemmes d'Andigne (FR). **DEFORGES, Olivier** [FR/FR]; 37 rue Jacques de Corbiere, F-35 150 Amanlis (FR). **BABEL, Marie** [FR/FR]; 12 rue des Saules, F-35690 Acigne (FR).

(74) **Agent: STREIT, Arend;** Deutsche Thomson OHG, European Patent Operations, Karl-Wiechert-Allee 74, 30625 Hannover (DE).

(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, QA, RO, RS, RU, RW, 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, RW, 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))*

(54) Title: METHOD AND DEVICE FOR RECONSTRUCTING A SELF-SIMILAR TEXTURED REGION OF AN IMAGE

(57) Abstract: The invention proposes a method for reconstructing a self-similar textured region of an image. Said method comprises determining pixels of a part of the self-similar textured region by copying sample pixels from a sample part of the self-similar textured region, the sample pixels being selected using a neighbourhood matching, wherein a size of neighbourhoods used for matching is selected based on an analysis of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part. The analysis of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part allows for determining the neighbourhood size close to a feature size of the texture.

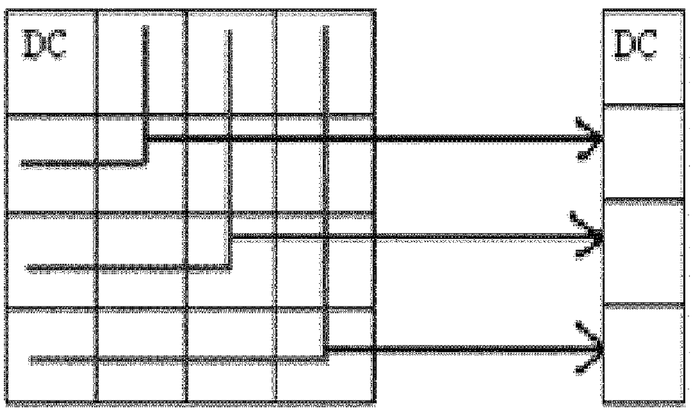


Fig. 6

WO 2012/072402 A1

Method and device for reconstructing a self-similar textured region of an image

TECHNICAL FIELD

The invention is made in the field of reconstruction of self-similar textured image regions.

BACKGROUND OF THE INVENTION

Self-similar textured regions in images induce high bit rates in encoding, in particular but not only in high definition encoding, while at the same time raise only limited interest by an observer. The interest of the observer is only focused on such regions in case the region shows discontinuities in structure or luminance.

In principal, the self-similarity of the texture allows for reducing the bit rate by encoding of only a sample part of the textured region and reconstruction of pixels of the non-encoded further part of the textured region by copying pixels of the sample part. Reconstruction is also known as synthesizing.

For instance, Li-Yi Wei and Marc Levoy: "Fast texture synthesis using tree-structured vector quantization", 2000, *Proc. of the 27th annual conference on Computer graphics and interactive techniques* (SIGGRAPH '00), ACM Press/Addison-Wesley Publishing Co., New York, NY, USA, 479-488, proposed a pixel-based reconstruction scheme in which a part of a texture region is reconstructed based on a pixel by pixel selection process.

Selection of a sample pixel for use for reconstruction of a given non-encoded pixel can be based on maximal similarity of a neighbourhood of the given non-encoded pixel with a neighbourhood of the sample pixel among sample pixel candidates .

SUMMARY OF THE INVENTION

The selection of the sample pixel dependents on the size of the neighbourhood used for selection. Different neighbourhood sizes can result in different sample pixels for reconstruction of a same non-encoded pixel. Neighbourhoods larger than a feature size of the texture in principle are suited for reproducing the texture well but require large sample parts for actually reproducing the texture in good visual quality. Neighbourhoods smaller than the feature size of the texture are resulting in poor reproductions. Thus, it is desirable to provide a method and device for reconstruction of a self-similar textured region of an image which adaptively selects the neighbourhood size close to the feature size of the texture .

The inventors therefore propose the method of claim 1 and the device of claim 3 .

Said method comprises determining pixels of a part of the self-similar textured region by copying sample pixels from a sample part of the self-similar textured region, the sample pixels being selected using a neighbourhood matching, wherein a size of neighbourhoods used for matching is selected based on an analysis of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part.

In an embodiment, the method further comprises the steps of receiving a bit stream in which the sample part of the self-similar textured region is encoded and decoding the sample part

In a further embodiment of the method the size of the neighbourhoods used for matching is adaptively selected by determining the coefficients by applying a DCT transformation on each of the differently sized blocks, determining, for each of the differently sized blocks, an associated sequence of descriptors wherein each descriptor is determined using sums of coefficients summed along parallel paths, selecting that sequence of descriptors which is the sequence associated with the smallest block size among those sequences which are not monotone decreasing and determining the size of the neighbourhoods using a size of the differently sized block associated with determined sequence.

Said device comprises a processing device. The processing device is adapted for determining pixels of a further part of the self-similar textured region by copying sample pixels from a sample part of the self-similar textured region, the sample pixels being selected using a neighbourhood matching, wherein the processing device is adapted for selecting a size of the neighbourhoods used for matching using an analysis of sequences of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part.

In an embodiment, said device further comprises a receiver and a decoder. The receiver is adapted for receiving a bit stream in which the sample part of the self-similar textured region is encoded and the decoder is adapted for decoding the sample part.

The inventive concept can also be applied on an encoding device for determining suitable sample part size and/or for determining the sized of the non-encoded part or on both.

If applied on encoder side, the selected neighbourhood size can further be transmitted to a decoder.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the invention are illustrated in the drawings and are explained in more detail in the following description. The exemplary embodiments are explained only for elucidating the invention, but not limiting the invention's disclosure, scope or spirit defined in the claims.

In the figures:

Fig. 1 depicts an exemplary DCT transform for an 8x8 block with exemplary parallel paths overlaid;

Fig. 2 depicts a basic prior-art pixel based reconstruction scheme as proposed by Wei and Lehoy ;

Fig. 3 depicts exemplary descriptor curves for different sized blocks;

Fig. 4 depicts further exemplary descriptor curves for different sized blocks;

Fig. 5 depicts an exemplary texture reconstruction based encoding-decoding framework, and

Fig. 6 depicts further exemplary parallel paths.

EXEMPLARY EMBODIMENTS OF THE INVENTION

Textures, defined as stationary regions, can vary from regular or near-regular textures, in which a pattern is recopied at different locations (brick wall), to stochastic noisy textures (sand, grass...) .

This invention proposes a new characterization step, which can be applied in the field of computer graphics for auto-adaptive algorithm and image/video compression scheme. The invention is based on the study of descriptors computed from the 2D Discrete Cosinus Transform (DCT) coefficient depicted in figure 1 for a 8x8 block. After having computed DCT coefficients of a block of a self-similar textured image region, descriptor vector components are computed from AC coefficients crossed by parallel paths centered on the DC coefficient, for example circles centered on the DC coefficient as exemplarily depicted in Fig. 1. The descriptor vector components correspond to the sums of coefficients that are crossed over by these parallel paths. The sums can be computed over equidistant parallel paths. Further the urns can comprise weighting factors for the coefficient summed up, the weigthing factors depending on the length of the path section crossing the respective coefficient. Then, at least two sizes must be tested to select the better by studying the variation of the descriptor vector.

The DCT coefficients are computed from:

$$C(i,j)=\frac{2}{N}\alpha_i\alpha_j\sum_{x=0}^{N-1}I(x,y)\cos\left(\frac{(2x+1)i\pi}{2N}\right)\cos\left(\frac{(2x+1)j\pi}{2N}\right)$$

Where I(x,y) corresponds to the luminance value at position (x,y), N is the size of the support block, and α_k following :

$$\alpha_k=\begin{cases}\frac{1}{\sqrt{N}} & si\quad i=0\\ \sqrt{\frac{2}{N}}\cos\left(\frac{(2j+1)i\pi}{2N}\right) & si\quad i>0\end{cases}$$

Then figure 1 shows the first circles CI and C2 representing the two first components of the descriptor vector since the DC value is not kept for average luminance invariance. Descriptors can be computed following:

$$D_{DCT}(\lambda) = \int_{\theta=0}^{\frac{\pi}{2}} \left| C(\lambda,\theta) \right|^2 d\theta$$

where C corresponds to the DCT coefficient at position $(\lambda\cos\theta, \lambda\sin\theta)$ in transform domain.

The descriptor vector components characterize the texture of the transformed block. First information lies in the feature sizes of patterns inside a texture region. Synthesis algorithms, especially pixel-based techniques, are based on the comparison between groups of pixels. Figure 2 depicts a basic prior-art pixel based reconstruction scheme as proposed by Wei and Lehoy. The causal neighborhood of the current pixel to synthesize (in red), is compared to the same shaped window at every location in the patch, the one that minimize a L2 norm comparison is chosen and the candidate sample pixel from the patch is copied to current location.

The inventors noticed from texture results computed with different sizes of neighborhood that sizes greater than the feature size of the snake skin are able to produce visually good results, while lower sizes are definitely not. Moreover, this size must also not to be too large because it reduces the candidate set of pixels depending of the patch size.

A first component of the descriptor vector is computed from coefficients crossed over by circle CI shown in figure 1. So it represents a single variation of luminance over the block in every direction. C2 represents a 1-periodic variation over the block and other coefficients are computed from higher frequencies so more detailed patterns. If the first component is the greatest value of the descriptor vector, the main pattern has a predominant uniform variation over the block. Its feature size is thus greater than the blocks size for computing DCT descriptors.

Therefore, if the first component has the greatest value, the descriptor vector is monotone and decreasing and the block size is not sufficient for being used as neighborhood in texture synthesis algorithms. Conversely, if other components are predominant (non monotone curve) , the main pattern appears to be included into the block. Thus reconstruction can be based on a comparison of neighbourhoods with a correspondingly selected size.

Figure 3 presents an exemplary case in point in order to better understand the descriptor curves study. In the example, a texture patch from "the matrix" is chosen which is composed of a main pattern of size about 12x12 pixels (distance between two neighboring figure centers) . Curves represent the average descriptor of different sizes over the patch on the left.

According to the previous reasoning, an 8x8 size is not enough, while with size 16x16, higher frequencies are predominant, so the main pattern can be include in a 16x16 block. Using a 32x32 neighborhood is also possible but it means that the patch has to be large enough to contain a large set of 32x32 blocks, which is not always possible in video compression domain for example, where segmented texture regions are not large enough. Figure 4 shows another example with gravels. The tiny gravels can be synthesized with a 5x5 neighborhood for practical purposes.

Texture synthesis can be used as an efficient compression technique for encoding of texture regions. Indeed, detailed texture regions are difficult to deal with, using classical transform-based compression schemes. Figure 4 presents an exemplary synthesis-based framework. After having segmented textures at encoder side by a texture analyzer, large texture regions are removed from sent bit-stream, only a set of sample texture blocks, surrounding removed regions for instance, are kept to be used as patch at decoder side. The decoder first builds the image with edge blocks and patches; a texture synthesizer then fills the missing textures to output complete images.

In this context, DCT descriptors can be useful for different aspects.

First, after having segmented textures at encoder side, descriptors can be used at encoder side to decide whether texture synthesizer at decoder side is able to reconstruct this kind of texture or not. Further, the encoder can decide how much of the textured region can be omitted from encoding and how much is need as sample by the decoder. And, the encoder can send the neighbourhood size for this texture region as side information. If no side information regarding the neighbourhood size is received by the decoder, the decoder can determine DCT descriptors from a received sample and then use them for determining an appropriate neighbourhood size for the reconstruction process .

A variety of parallel paths for computing descriptor vector components can be used. Figure 6 shows another example of a descriptor vector on the right, computed from parallel equidistant paths over a 4x4 DCT block on the left.

Coefficients correspond to the sum of DCT coefficients crossed by dashed lines depicting exemplary paths. Since DC is not kept, the exemplary descriptor vector gets three components as shown by arrows.

The invention allows getting texture features to parameterize texture synthesis algorithms, depending on type, shape and featured size of texture patterns to synthesize .

.

CLAIMS :

1. Method for reconstructing a self-similar textured region of an image, said method comprising the steps of

- determining pixels of a part of the self-similar textured region by copying sample pixels from a sample part of the self-similar textured region, the sample pixels being selected using a neighbourhood matching, wherein a size of neighbourhoods used for matching is selected based on an analysis of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part.

2. Method of claim 1, said method further comprising the steps of

- receiving a bit stream in which the sample part is encoded, and

- decoding the sample part.

3. Method of claim 1 or 2, wherein the size of the neighbourhoods used for matching is adaptively selected by

- determining the coefficients by applying a DCT transformation on each of the differently sized blocks,

- determining, for each of the differently sized blocks, an associated sequence of descriptors wherein each descriptor is determined using sums of coefficients summed along parallel paths,

- selecting that sequence of descriptors which is the sequence associated with the smallest block size among those sequences which are not monotone decreasing and

- determining the size of the neighbourhoods using a size of the differently sized block associated with selected sequence .

4. Device for reconstructing a self-similar textured region of an image, said device comprising

– a processing device adapted for determining pixels of a part of the self-similar textured region by copying sample pixels from a sample part of the self-similar textured region, the sample pixels being selected using a neighbourhood matching, wherein the processing device is adapted for selecting a size of the neighbourhoods used for matching using an analysis of sequences of descriptors computed from coefficients of DCT transform of differently sized blocks of the sample part.

5. Device of claim 4, said device further comprising

– a receiver for receiving a bit stream in which the sample part is encoded, and

– a decoder for decoding the sample part.

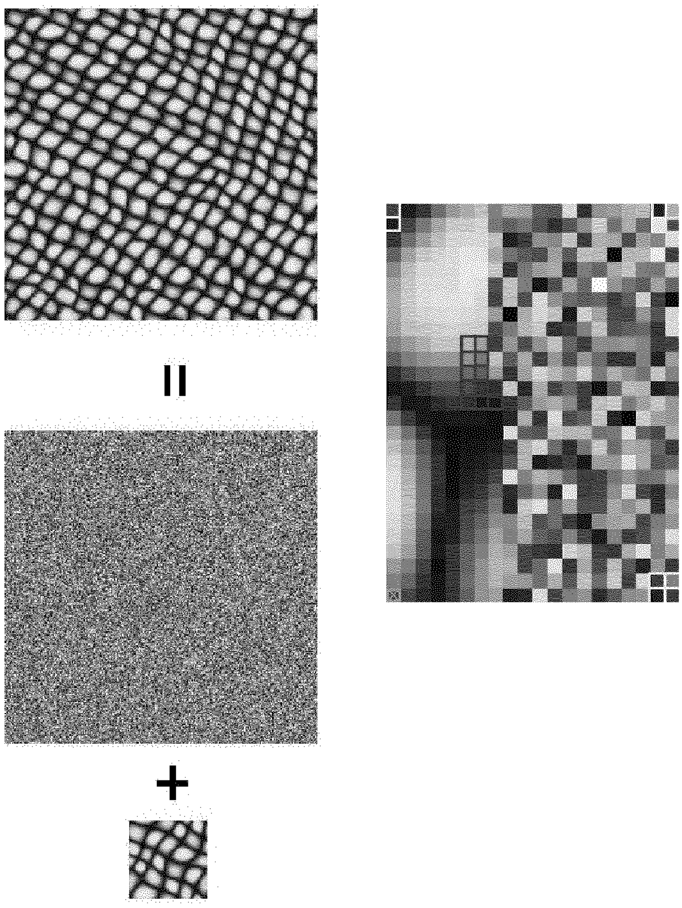


Fig. 2

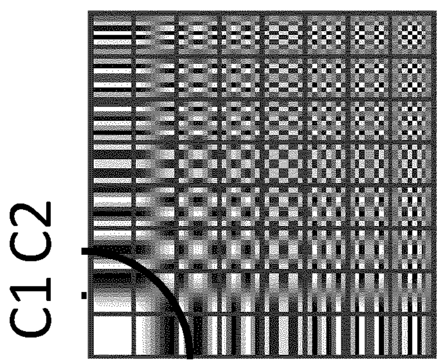
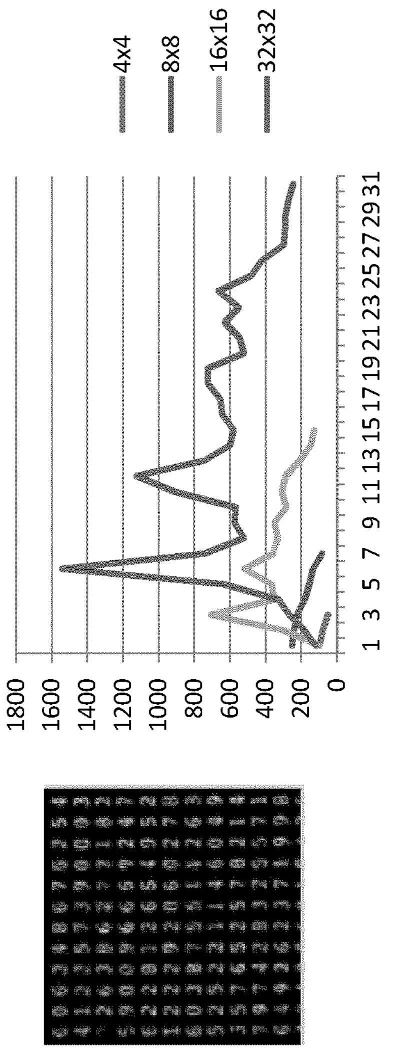
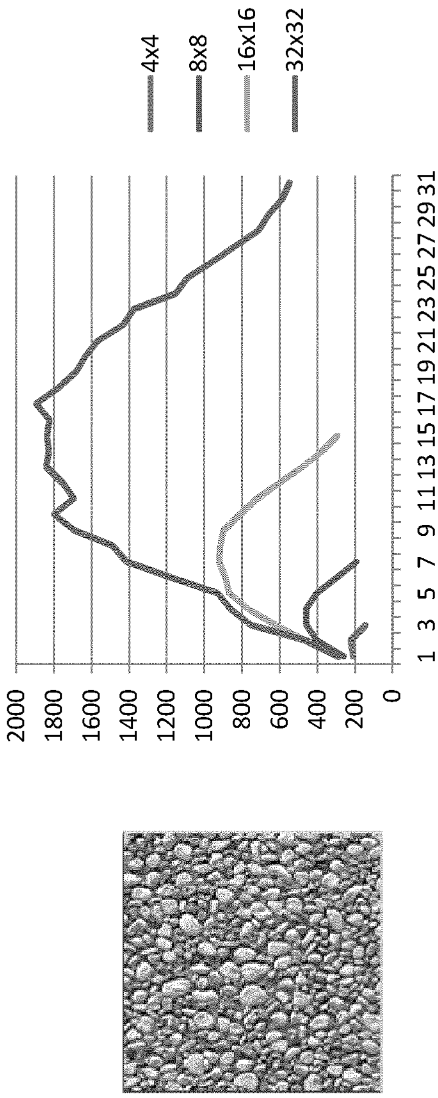


Fig. 1



0
200
400
600
800
1000
1200
1400
1600
1800
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
4x4
8x8
16x16
32x32

Fig. 3



0
200
400
600
800
1000
1200
1400
1600
1800
2000
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
4x4
8x8
16x16
32x32

Fig. 4

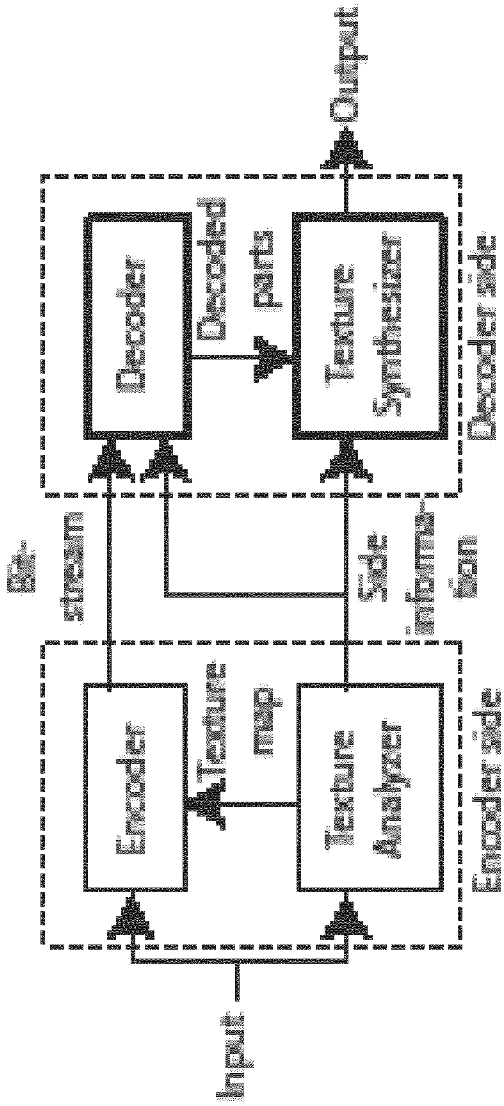

Input
Encoder
Texture map
Texture Analyzer
Encoder side
Bit-stream
Side information
Decoder
Decoded parts
Texture Synthesizer
Decoder side
Output

Fig. 5

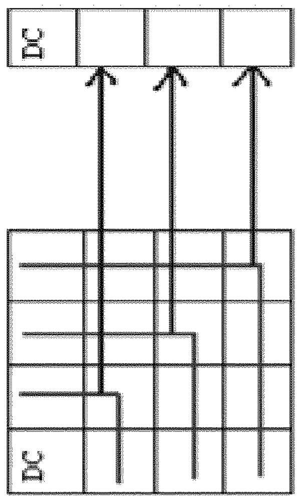

DC
DC

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/069855

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T11/00 G06T7/40
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)
G06T

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WEI L-Y ET AL: "FAST TEXTURE SYNTHESIS USING TREE-STRUCTURED VECTOR QUANTIZATION", COMPUTER GRAPHICS. SIGGRAPH 2000, CONFERENCE PROCEEDINGS. NEW ORLEANS, LA, JULY 23 - 28, 2000; NEW YORK, NY, ACM, US, 23 July 2000 (2000-07-23), pages 479-488, XP001003589, cited in the application the whole document ----- -/-	1-5

[X] 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

"E" earlier document but published on or after the international filing date

"L" documentwhich 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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 February 2012	17/02/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Pierfederici, A

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JOAN S WESZKA ET AL: "A Comparative Study of Texture Measures for Terrain Classification", IEEE TRANSACTIONS ON SYSTEMS, MAN AND CYBERNETICS, IEEE INC. NEW YORK, US, vol. SMC-5, no. 4, 1 April 1976 (1976-04-01), pages 269-285, XP011302082, page 269, right-hand column, paragraph 3 -----	1-5
Y	MANIAN V ET AL: "On the use of transform features for SAR image classification", GEOSCIENCE AND REMOTE SENSING SYMPOSIUM PROCEEDINGS, IGARSS '98. SEATTLE, WA, USA 6-10 JULY 1998, NEW YORK, NY, USA, IEEE, US, vol. 2, 6 July 1998 (1998-07-06), pages 1068-1070, XP010293047, page 1068, left-hand column, paragraph 2 - paragraph 3 -----	1-5
Y	ALPAR0NE L ET AL: "TEXTURE-BASED ANALYSIS TECHNIQUES FOR THE CLASSIFICATION OF RADAR IMAGES", IEE PROCEEDINGS F. COMMUNICATIONS, RADAR & SIGNALPROCESSING, INSTITUTION OF ELECTRICAL ENGINEERS. STEVENAGE, GB, vol. 137, no. 4 PART F, 1 August 1990 (1990-08-01), pages 276-282, XP000140287, page 276, right-hand column, paragraph 3 - paragraph 4 page 277, right-hand column, paragraph 2 - paragraph 5; figure 1 -----	1-5
A	STRAND J ET AL: "LOCAL FREQUENCY FEATURES FOR TEXTURE CLASSIFICATION", PATTERN RECOGNITION, ELSEVIER, GB, vol. 27, no. 10, 1 October 1994 (1994-10-01), pages 1397-1406, XP000477900, the whole document -----	1-5

1