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(74) Agent: **GILL JENNINGS & EVERY**; Broadgate House,
7 Eldon Street, London EC2M 7LH (GB).

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(71) Applicant (for all designated States except US): **DE LA RUE INTERNATIONAL LIMITED** [GB/GB]; De La Rue House, Jays Close, Basingstoke, Hampshire RG22 4BS (GB).

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(72) Inventor; and

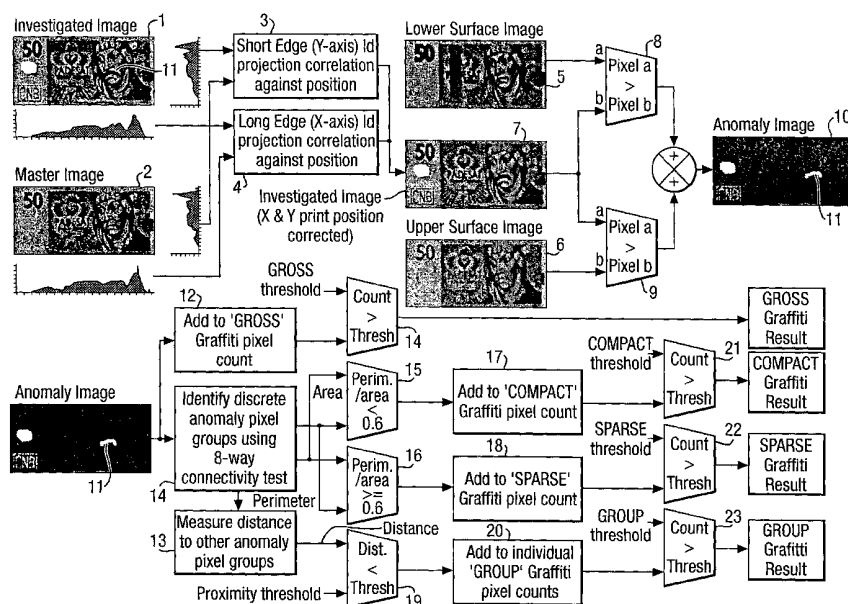
(75) Inventor/Applicant (for US only): **KLEVTSOV, Valery, Alekseevich** [RU/RU]; 1 Demakova Street, Apartment 163, Novosibirsk, 630128 (RU).

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[Continued on next page]

(54) Title: MONITORING METHOD



(57) **Abstract:** A method of monitoring markings (11) made on printed documents (1) comprises obtaining a digital representation of a face of a document by determining single or multiple colour component content of pixels of the representation; comparing (8,9) the colour component content of each pixel of the representation with a range extending between upper and lower thresholds for the corresponding pixel of an acceptable unmarked document and generating a corresponding anomaly pixel (10) if the pixel value falls outside the range; and determining (21-24) the presence of a marking (11) if the resulting anomaly pixels satisfy predetermined conditions.



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- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

MONITORING METHOD

The invention relates to a method of monitoring documents and in particular monitoring markings made on printed documents.

In a number of applications, there is a need to be able to detect markings such as graffiti made on previously printed documents such as documents of value including banknotes and the like. This should be distinguished from detecting the soil condition of documents since soiling is typically at a substantially constant level across the document whereas the markings with which this invention are concerned include lines, regions of defacement such as ink stains and the like.

EP-A-0165734 discloses a method for comparing an incoming banknote with a master pattern so as to take account of variations in the appearance of a particular pixel. It should be noted, however, that this is concerned with the inspection of documents (or objects) that have not been in circulation.

US-A-6,012,565 discloses the classification of documents but is not concerned with detection of markings on documents.

WO-A-00/26861 is concerned with a currency recognition process and also considers soil detection. However, as explained above, soil detectors are not able to detect markings such as graffiti.

In accordance with the present invention, a method of monitoring markings made on printed documents comprises obtaining a digital representation of a face of a document by determining single or multiple colour component content of pixels of the representation; comparing the colour component content of each pixel of the representation with a range extending between upper and lower thresholds for the corresponding pixel of an acceptable unmarked document and generating a corresponding anomaly pixel if the pixel value falls outside the range; and determining the presence

of a marking if the resulting anomaly pixels satisfy predetermined conditions.

The invention enables markings such as graffiti to be detected and allows the degree of graffiti to be determined. This provides the user with the ability to be more (or less) tolerant of a particular form of defacement.

Typically, a single colour component or grey level value will be determined for each pixel but in more sophisticated examples a multi-colour component representation of each pixel could be obtained.

The upper and lower thresholds can be obtained by a variety of techniques. For example, one or more unmarked documents could be examined and an average value determined for each pixel. This average value could then be modified by adding a suitable value or by multiplying by a suitable value to obtain the upper and lower thresholds. Alternatively, a variety of unmarked documents, used and unused, could be analysed and a record kept of the least bright and brightest values for each pixel which can then be used to constitute the lower and upper thresholds.

In the preferred approach, the images of a representative sample of the population of the banknotes in circulation are captured; these must exhibit no defacement. Within that population, the darkest pixels in each x,y position are found and are used to make up the lower surface image. A similar process using the lightest pixels is employed to generate the upper surface image.

These stored values could then be further modified using multiplicative or additive coefficients to generate final upper and lower thresholds prior to comparison with the input pixel values.

Once the anomaly pixels have been identified, the method then seeks to determine whether or not one or more predetermined conditions are satisfied. These predetermined conditions can be selected from:

- a) the total number of anomaly pixels being greater than a "gross" threshold;

- b) the total number of anomaly pixels within a marking having a perimeter to area ratio greater than a first predetermined parameter being greater than a "sparse" threshold;
- 5 c) the total number of anomaly pixels within a marking having a perimeter to area ratio less than a second predetermined parameter being greater than a "compact" threshold; and
- 10 d) the total number of anomaly pixels within a specified distance of another anomaly pixel being greater than a "group" threshold.

Typically, each of these conditions will be determined and more than one may indicate a positive result thus
15 indicating the type of graffiti or other markings present on the document. The user can then decide whether the level of markings is acceptable allowing, in the case of banknotes, the banknotes to be recirculated, or unacceptable in which case the banknotes should be
20 withdrawn from circulation.

Although typically the representations will be those which can be seen under visible illumination, they could include instead or in addition representations visible under normally non-visible irradiation such as ultraviolet
25 or infrared.

The invention is applicable to a wide variety of processes including document sorting, counting, dispensing, validating and recirculating. It can be used for processing a variety of documents, including security
30 documents and documents of value such as banknotes.

The invention can be implemented using conventional pattern recognition hardware and is particularly suitable for use in the De La Rue Vision™ system.

An example of a method according to the invention will
35 now be described with reference to the accompanying drawings, in which:-

Figure 1 is a flow diagram of the method;

Figures 2A-2C illustrate an image of a good quality banknote, an image of the banknote with each pixel having its highest value, and an image of the same banknote with each pixel having its lowest value respectively; and,

5 Figures 3A and 3B illustrate examples of a compact pixel and a sparse pixel respectively.

Figure 1 illustrates an image of a banknote under test at 1 and a corresponding master image 2 of the same banknote which will be stored in memory. In many cases, more than one master image will be stored, for example
10 corresponding to the same banknote in different orientations and also to banknotes of different denominations. In order to be able to carry out the method, it is first necessary to correlate the investigated
15 image 1 with its corresponding master image 2. This can be achieved in a variety of ways once the investigated image 1 has been digitized and for example is conveniently achieved by comparing the location of known printed features on the two images. This is achieved by producing
20 one-dimensional "projections" of mean column/row pixel intensity in the direction of the long and short edges of the note (steps 3,4). These are then correlated with corresponding master image projections at incremental positions around the origin. The position yielding the
25 highest correlation score is judged to be the correct position. This positional offset measurement is added to the investigated image 1 when comparing with the surface images in the succeeding steps.

For each master image 2, the system stores a
30 corresponding lower surface image 5 and an upper surface image 6. These are shown in more detail in Figures 2C and 2B respectively with an image of a good quality note, corresponding to the master image 2, shown in Figure 2A.

The content of each pixel of the upper surface image
35 6 has been obtained by reviewing a large number of genuine notes and recording the brightest value of each pixel in the group of notes. Similarly, the lower surface image 5

is obtained by recording the least bright or lowest value in the group for each pixel.

The position corrected version of the investigated image 7 is then compared, pixel by pixel, with the lower and upper surface images 5,6. If the amplitude of the pixel with position (x_1, y_1) in the investigated image is greater than the amplitude of the corresponding pixel with position (x_1, y_1) in the upper surface image then this pixel is classed as an anomaly pixel, causing the pixel with position (x_1, y_1) in an anomaly image 10 to become set. The same test is applied to the investigated and lower surface images, i.e. if investigated image pixel amplitude < lower surface image pixel amplitude then set anomaly pixel.

The result of this process is the generation of an "anomaly image" 10 where it can be seen that a marking 11 on the investigated image 1 has been identified. However, in order for the process to detect the marking, a further analysis of the anomaly image 10 is required. In this process, each anomaly pixel is reviewed and categorised. The method thus scans the anomaly image pixel-by-pixel. When it reaches an anomaly pixel, a "gross" graffiti pixel count is incremented (step 12).

In a step 14, groups of anomaly pixels are reviewed using an 8-way connectivity test to determine their area and perimeter, i.e. the anomaly pixel under examination (centre pixel in a 3x3 grid) is directly bordered by another anomaly pixel (one or more of the 8 outlying pixels in the same 3x3 grid). This enables the pixels within these groups to be characterized as either "sparse" or "compact" depending upon the ratio between the perimeter and the area of the group. Figure 3A illustrates a typical example of a group of pixels classified as compact (perimeter/area ratio = 0.35) and Figure 3B an example of the group of pixels classified as sparse (perimeter/area ratio = 1.04). This classification is achieved by feeding the area and perimeter information to comparators 15,16 where the ratio is compared with a parameter, in this case

0.6. The parameters need not be the same. Depending upon the outcome of these comparisons, an appropriate one of a compact count 17 and a sparse count 18 is incremented.

Following determination (step 13) of the distance
5 between an anomaly pixel and another anomaly pixel, this distance is compared with a proximity threshold in a step 19 and if the distance is less than the proximity threshold the group count is incremented (step 20).

The counts determined in steps 17,18,20 are then
10 compared with respective thresholds in steps 21-23 respectively to yield final results along with the result of comparing the gross count with a threshold (step 24).

These results can then simply be stored and/or
displayed and/or utilized by the machine carrying out the
15 analysis to direct the manner in which the note is to handled. For example, notes which indicate an unacceptable level of graffiti could be diverted to a cull station or cause the machine to stop.

The "compact" count exceeding a threshold will
20 indicate the presence of a stain or other "solid" defacement, the "sparse" count exceeding a threshold will indicate the presence of handwriting or drawing, and the "group" count exceeding a threshold will indicate coordinated defacement such as a bank's ink stamp.

25 The invention can, of course, be implemented in software, hardware or firmware as will be apparent to a person of ordinary skill in the art.

CLAIMS

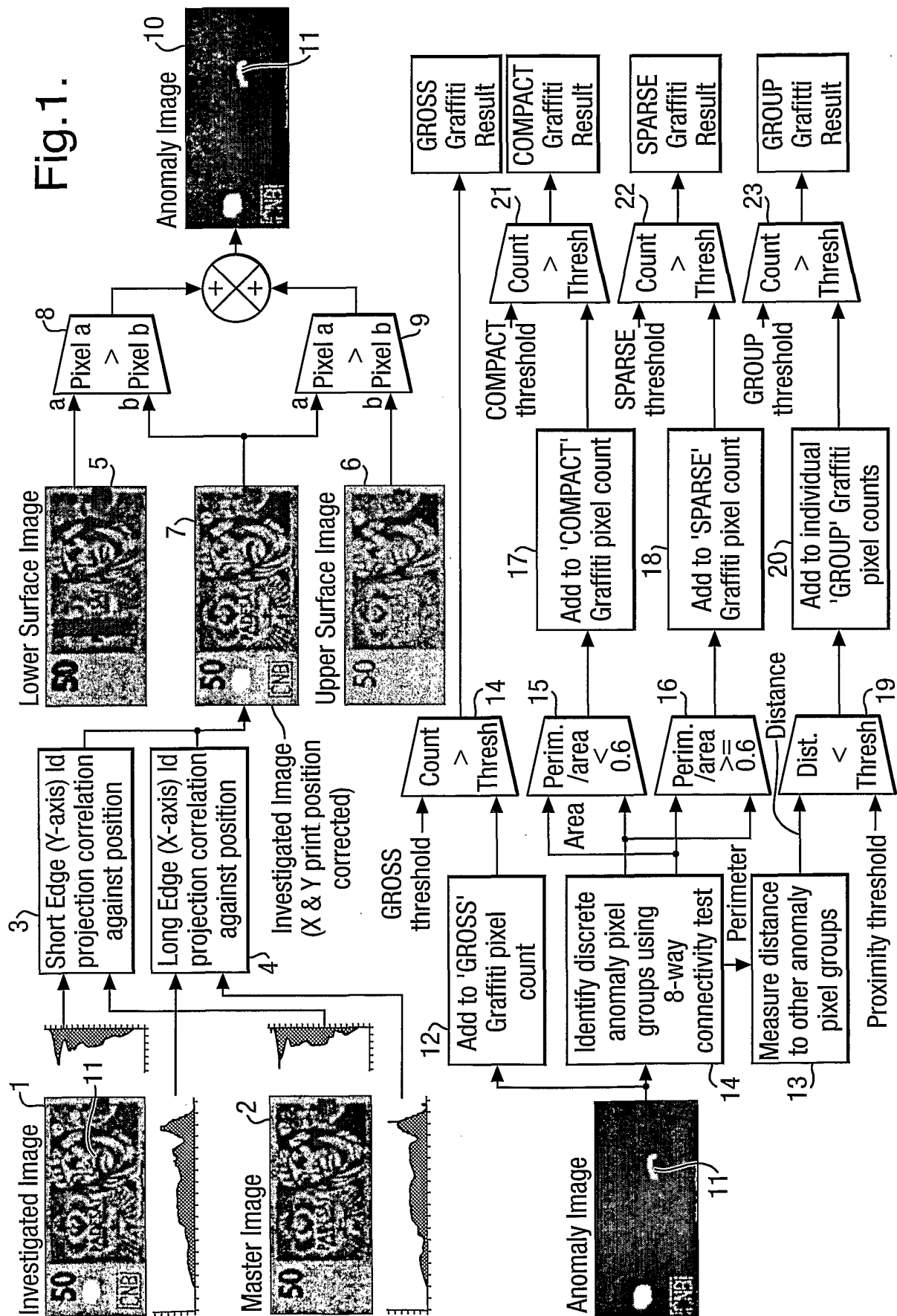
1. A method of monitoring markings made on printed documents, the method comprising obtaining a digital representation of a face of a document by determining single or multiple colour component content of pixels of the representation; comparing the colour component content of each pixel of the representation with a range extending between upper and lower thresholds for the corresponding pixel of an acceptable unmarked document and generating a corresponding anomaly pixel if the pixel value falls outside the range; and determining the presence of a marking if the resulting anomaly pixels satisfy predetermined conditions.
2. A method according to claim 1, wherein the upper and lower thresholds are obtained by defining a range about an average value for each pixel.
3. A method according to claim 1, wherein a number of unmarked documents are analysed, the least bright and brightest values for each pixel being used directly or following modification to constitute the lower and upper thresholds respectively.
4. A method according to any of the preceding claims, wherein the predetermined conditions are selected from one or more of:
- a) the total number of anomaly pixels being greater than a "gross" threshold;
 - b) the total number of anomaly pixels within a marking having a perimeter to area ratio greater than a first predetermined parameter being greater than a "sparse" threshold;
 - c) the total number of anomaly pixels within a marking having a perimeter to area ratio less than a second predetermined parameter being greater than a "compact" threshold; and

d) the total number of anomaly pixels within a specified distance of another anomaly pixel being greater than a "group" threshold.

5. A method according to any of the preceding claims,
5 wherein the digital representation of a face of a document corresponds to the appearance of that face under visible illumination.

6. A method according to any of the preceding claims,
wherein the document comprises a security document or
10 document of value, such as a banknote.

Fig. 1.



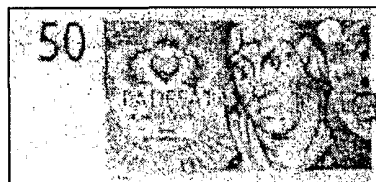
2/2

Fig.2(a).



2)

Fig.2(b).



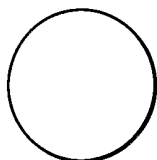
6)

Fig.2(c).



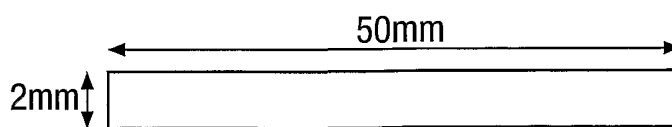
5)

Fig.3(a).



Radius = 5.64mm
 Area = 100sqmm
 Perimeter = 35.4
 Perimeter/Area ratio = $35.4/100$
 = 0.35

Fig.3(b).



Area = 100sqmm
 Perimeter = 104mm
 Perimeter/Area ratio = $104/100$
 = 1.04

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 02/01312

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G07D7/18

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)

IPC 7 G07D

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 165 734 A (BANK OF ENGLAND) 27 December 1985 (1985-12-27) cited in the application	1, 2, 4-6
Y	page 1, line 7 - line 16 page 1, line 26 - line 32 page 2, line 11 - line 22 page 4, line 2 - line 10 page 6, line 27 - line 33 page 9, line 2 - line 15 page 12, line 15 - line 27 page 13, line 9 - line 17 page 16, line 23 - line 27 page 17, line 15 - line 24 page 23, line 14 - line 22 page 25, line 1 - line 11 --- -/-	3



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

° Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

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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)

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

9 August 2002

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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, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Verhoef, P

INTERNATIONAL SEARCH REPORT

Intern~~ational~~ Application No

PCT/GB 02/01312

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 012 565 A (MAZUR RICHARD A) 11 January 2000 (2000-01-11) cited in the application abstract column 1, line 45 - line 59 column 2, line 59 - line 66 -----	3
X	WO 00 26861 A (RUE DE INT LTD ;XU BO (US); DEFEO MICHAEL L (US); DENISON JACK (US) 11 May 2000 (2000-05-11) cited in the application abstract page 2, line 15 -page 3, line 23 -----	1,4,6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 02/01312

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0165734	A	27-12-1985	AT 78354 T	15-08-1992
			AU 587747 B2	24-08-1989
			AU 4373185 A	02-01-1986
			CA 1281125 A1	05-03-1991
			DE 3586339 D1	20-08-1992
			DE 3586339 T2	11-02-1993
			DK 282185 A	23-12-1985
			EP 0165734 A2	27-12-1985
			ES 544425 D0	01-04-1987
			ES 8704649 A1	16-06-1987
			ES 557059 D0	16-12-1987
			ES 8801455 A1	01-03-1988
			GB 2160644 A ,B	24-12-1985
			GR 851508 A1	25-11-1985
			HK 89888 A	11-11-1988
			IE 56706 B1	06-11-1991
			IN 167911 A1	05-01-1991
			JP 1942920 C	23-06-1995
			JP 6069219 B	31-08-1994
			JP 61082595 A	26-04-1986
			JP 1846428 C	07-06-1994
			JP 2118886 A	07-05-1990
			JP 5059473 B	31-08-1993
			JP 1835809 C	11-04-1994
			JP 2132564 A	22-05-1990
			JP 5047866 B	19-07-1993
			KR 9210482 B1	28-11-1992
			MX 172127 B	06-12-1993
			MX 159061 A	13-04-1989
			NO 852520 A ,B,	23-12-1985
			US 5537615 A	16-07-1996
			US 5255331 A	19-10-1993
			ZA 8504361 A	30-04-1986
US 6012565	A	11-01-2000	AU 7159098 A	27-11-1998
			EP 0981806 A1	01-03-2000
			WO 9850892 A1	12-11-1998
			US 6237739 B1	29-05-2001
			US 6241069 B1	05-06-2001
WO 0026861	A	11-05-2000	AU 6359799 A	22-05-2000
			EP 1044434 A1	18-10-2000
			WO 0026861 A1	11-05-2000
			US 6234294 B1	22-05-2001